SCHOOL SCIENCE AND MATHEMATICS

VOL. X. No. 3 CHICAGO, MARCH, 1910 WHOLE No. 77

THE MECHANICS OF FLIGHT.*

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During the last two years the civilized world has been surprised by the achievement of mechanical flight, a thing that until very recently has been considered impossible even by the most enlightened men of their times. You remember the passage in Goethe's *Faust* where Faust and Wagner on their Easter Sunday's walk come to a hill and watch the setting sun, and Faust expresses a longing for wings to lift him off and carry him over hills and valleys as far as the sea and farther, and then concludes, "Ach, zu des Geistes Flügeln wird so leicht kein körperlicher Flügel sich gesellen." I think Goethe would have been very much surprised if anyone might have told him that one hundred years hence this bodily wing would actually be at his disposal.

For physicists and others noticing the experiments that have been carried on in the last twenty years, the surprise, however, has not been so great. I should like to talk to you upon the mechanical principles that underlie mechanical flight and that make us understand it, and, I think, to a certain extent, even allow us to predict in what direction the development will take place. Isaac Newton was one of the first to form an idea of the resistance of air. He looked at the resistance of a body against which air is moving in this way: as if small particles of matter were thrown against the body, and by impact pressed on it without interfering with one another. Now, as long as you regard a plane surface normal to the current of air, you get the pressure by reasoning on these lines approximately right. That is probably the reason why Newton's view was so largely adopted and so long adhered to by physicists and engineers.

Consider a plane of area A, and let us imagine that particles

*Stenographic report of an informal talk given before the Physics Club of New York, Dec. 4, 1909.

are thrown against it with the velocity v. If we consider the particles to be stopped by the plane, so that their velocity is changed from v to o, then mv would be, in absolute units, the force acting per unit of time as long as the particles are streaming against the plane, m being the whole mass that encounters the surface per unit of time. The volume of air that rushes against the surface in unit of time is a cylinder of base A and of the height of the velocity v. The area of the surface multiplied by the velocity would therefore be the volume of the air which is thrown against the area in unit of time. That, multiplied by the density ρ of the air, would be the mass; and this mass multiplied by v, would give the momentum, and that would be the force acting on the plane, if we simply assume that these particles thrown against the area are stopped. So we have the whole force equal to $\rho v^2 A$, or on the unit of area you would get the pressure ρv^2 in absolute measure. Now by actual experiments we find that this is nearly right. We find that the pressure for all plane surfaces of compact form like a circle or a square, is about $0.7\rho v^2$ in absolute measure. However, as soon as Newton's method is further carried out, we get altogether wrong. Take, for instance, a curved roof of a house. If we regard the roof as struck by a horizontal stream of particles which may rebound from the roof, but do not interfere with one another, then, of course, the resultant force on the roof would be somewhat downward—it would press on the roof. There would be on the rear side of the house no action at all; everything would be on the forward side of the house (Fig. 1). This is not in accordance with what we know of the actual action of the wind. The wind blowing over the curved roof of a house would have the tendency to lift off the roof, and in storms everyone may observe that roofs of houses are actually lifted off, and sometimes are carried high up into the air.

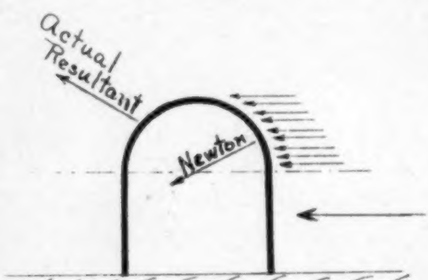

Fig. 1.

I have arranged a little experiment here to show you how the wind would act. I have fastened a piece of paper with two tacks on a board, and I curved this paper a little bit; and here we have a fan producing an artificial wind, and I let

this wind blow against the paper in a certain way. You will see that the movement of the paper (Fig. 2) cannot by any means be explained on Newton's theory that the pressure is caused by independent particles hitting the paper. The wind lifts the paper against the direction of its own movement. You cannot make that agree with the theory of Newton's particles striking the paper. The explanation is this: that Newton's supposition that the particles do not interfere with one another is altogether wrong. There is the real source of the error. The particles meeting the body do interfere with one another to a very large extent, so that if we actually want to show what happens with the plane area normal to the wind we would have to draw the stream lines of the air somewhat in this way (Fig. 3). The particles come around the surface, and here behind the surface we get something like this. That would be the actual thing that happens.

Fig. 2.

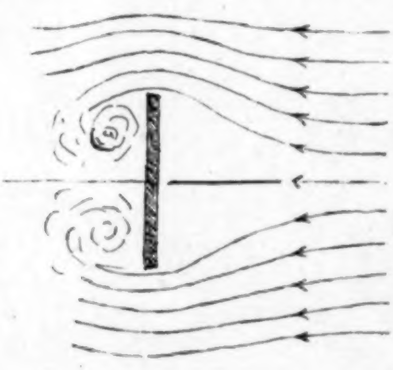

Fig. 3.

Consider a particle approaching the plane. Long before it reaches the surface it is already pressed out of the way, and so it comes about that the pressure on the front surface is much smaller than it would be by Newton's theory, while on the back part we have a suction, and a very large part of the whole resistance encountered is due to this suction on the other side. We have in the curved roof a resultant somewhat like Fig. 1, and we have a suction on the back part which causes this resultant upwards. In the same way an upward resultant force

causes this movement of the paper which you have seen just now. As the paper is held on one side, this upward resultant will lift it over.

The deviation from Newton's theory is still more marked in the case of a plane surface forming a small angle with the direction of the current of air. This has been investigated very carefully by Langley in this country and by Dines in England. If we take a plane surface inclined to the direction of the wind, and if we follow Newton's idea, we would say the particles arrive at the surface with a certain velocity indicated by the straight

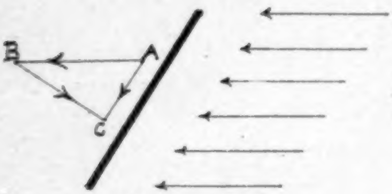

Fig. 4.

Fig. 5.

line AB (Fig. 4), and by the pressure of the body the velocity is changed by a vector BC vertical to the surface of the plane, so that the component of their velocity vertical to the plane is stopped, and only the tangential component AC remains, and the particles slide off without interfering with one another. The alteration of the velocity, the vector BC, vertical to the plane, we may express by $v \sin \alpha$, α being the angle BAC. This multiplied by the mass gives us the momentum that is imparted to the particles, and that measures the force that acts on the plane. The volume of the air meeting the surface in unit of time is a cylinder of section A $\sin \alpha$ and length v; that multiplied by the density ρ and multiplied by $v \sin \alpha$ would be the whole momentum, or the force in the direction vertical to the plane. Dividing by the area we get the pressure. The pressure of a plane at angle α is therefore equal to $\rho \sin^2 \alpha v^2$.

If we introduce ρv^2 as the pressure on the normal plane and denote it by P_{90}, the pressure P_α on the plane at angle α would according to Newton be equal to $P_{90} \sin^2 \alpha$. For small angles we could write α instead of $\sin \alpha$; therefore, $P_\alpha = P_{90}\alpha^2$. The pressure on a plane surface for a slight angle is, according to Newton's idea, equal to the pressure on the normal plane multiplied by the square of the angle. Now, the measurements by Langley and by Dines of the pressure on square planes, give

results which are essentially different from this formula of Newton's. They show that for small angles the pressure is about equal to $2P_{90}a$. That is to say, the pressure is not proportional to the square of the angle, but proportional to the angle itself. That we may say is the fundamental principle on which the action of the aëroplane, and the possibility of artificial flight, is based.

For smaller and smaller angles Newton's pressure would be a smaller and smaller fraction of the pressure that is actually observed. The reason of this is, of course, that the supposition which lies in Newton's idea that the particles do not interfere with one another is entirely wrong. They interfere to a very great extent. Consider the particles meeting the inclined plane (Fig. 5). They are running off the plane, and they are interfering to a very great extent with the particles that are coming, so that the plane has a much greater action than it would have if the particles did not interfere with one another. Langley was very quick to see what bearing his observations of the pressure on a slightly inclined plane had on the possibility of artificial flight. I will try to show you how this really gives us an insight into the workings of the aëroplane, and how we can make use of the pressure formula to understand something about the aëroplane, and, I think, even to predict something about the direction in which the development will go.

The real aëroplane is not a flat surface; it is curved. It has been found that the lifting power of a curved surface of the same area is still greater than that of a plane one. Let us, however, leave that point out of consideration, and let us make our calculations for a flat aëroplane. I will start with the formula of Langley. P_a is the pressure. P_aA is the force vertical to the plane. The plane makes an angle a with the direction of the movement. We take two components, a vertical component and a horizontal component. The vertical component is $P_aA \cos a$, and the horizontal component is $P_aA \sin a$. Now for a very small a, $\cos a$ is very nearly 1, and $\sin a$ is very nearly equal to a; therefore, we can just as well say the vertical component is P_aA, and the horizontal component is P_aAa. The horizontal component would give the dynamical resistance, the resistance which has to be overcome to equilibrate the horizontal component of the pressure. That is not the only horizontal resistance of the aëroplane; there will also be frictional resistance, quite independent of the angle, due to sur-

face friction and to the resistance of the other parts of the machine beside the supporting surface.

Now let us see how the resistance can be expressed. As soon as we imagine that we want to carry a certain weight W, then our vertical component must have a certain definite value, and be equal to the weight W measured with the same units, so that $W=P_a A$. Now let us introduce for P_a its value $2P_{90}aA$; or, for P_{90} we will introduce $0.7\rho v^2$. Thus we get $W=1.4\rho aAv^2$. This is a constant; therefore, for different speeds the angle a must be chosen accordingly. The density of the air, which does not change much, I will take as constant. For greater speed we must use a smaller angle to get the given lifting power.

Now let us look at the resistance. The resistance consists of two parts; first, the dynamical resistance $P_a Aa$; and secondly, the resistance that is independent of a. This second part of the resistance we know to be proportional to the square of the velocity. Therefore, let us denote it by bv^2, where b is a constant depending on the construction of the aëroplane. The first part of the resistance we can express by Wa, substituting W for $P_a A$. But as $W=1.4\rho aAv^2$, we can write $a=\frac{W}{1.4\rho Av^2}$. Substituting this expression for a, the dynamical resistance becomes $\frac{a}{v^2}$, where a is written for shortness to denote the constant $\frac{W^2}{1.4\rho A}$. For the whole resistance of the flying machine we therefore get this expression $\frac{a}{v^2}+bv^2$. One part is inversely proportional to the square of the velocity, and another part proportional to the square of the velocity. The work done in the unit of time, or the horse power, we may say, necessary to carry the aëroplane through the air is given by multiplying the resistance with the velocity. It is given by the expression $\frac{a}{v}+bv^3$. We conclude, therefore, that one part of the horse power decreases with the speed inversely proportional to the speed, and that the other part increases with the cube of the speed. You see at once that this gives us the remarkable fact that there is a certain speed for which the horse power is a minimum. For very small velocities $\frac{a}{v}$ is large and bv^3 small; for great velocities $\frac{a}{v}$ is small and bv^3 large. The horse power is large both for small

and great velocities. The velocity for which the horse power is a minimum is found by differentiating and making the differential coefficient equal to zero. Thus we find for this velocity $-\frac{a}{v^2}+3bv^2=0$. Let us denote this particular velocity by v'. It is the most economic speed with which to be supported in the air. If we want to go slower, we would have to apply more horse power. If we want to go quicker, we would also have to apply more horse power. It is the smallest speed for which an aëroplane can fly. When the machine slows down, when for instance the motor does not work properly, we see that at a certain speed the aëroplane cannot fly any longer. That is this speed v'. As far as my observations go the velocity v' for Delagrange's machine that I saw at Paris in the fall of 1908, was about 14 meters per second. That would be about 31 miles per hour. To understand this peculiar fact, you must consider that for a small velocity the angle would have to be increased to get the given lifting power. The increasing of the angle increases the horizontal resistance, and so it comes about that for velocities smaller than v' you would have to apply a larger horse power.

Now, I will introduce this velocity v' in the formula for the horse power. We have $\frac{a}{v'}=3bv'^3$; or, $\frac{a}{v}=bv'^3 \cdot \frac{3v'}{v}$. Substituting this in the formula for the work done per unit of time we get:

$$\text{Energy per second}=bv'^3\left[3\frac{v'}{v}+\left(\frac{v}{v'}\right)^3\right]$$

And now you see that the energy per second is proportional to the expression in brackets, and this expression in brackets has a minimum for $\frac{v}{v'}=1$; or, for $v=v'$. For $v=v'$ its value is equal to 4, and now we can calculate how the energy per second increases if we want to go with a greater speed. Let us calculate how the energy would increase if we want to go with double the speed. That gives a certain insight that I want to point out to you.

Speed	Energy per second
v'	$bv'^3\ 4$
$2v'$	$bv'^3\ 9.5$

This is to say, if we want to double our speed with the same machine, the energy per second increases in the proportion 9.5 to 4, or 2.4 to 1.

Now look how the energy increases with the dirigible balloon. With the dirigible balloon the resistance is proportional to the square of the speed only. Therefore the energy per second is equal to the resistance multiplied by the speed. As the resistance is proportional to the square of the speed, the energy per second for the dirigible balloon is therefore proportional to the cube of the speed. Therefore to double the velocity of the dirigible balloon, the energy per second would have to be increased proportional to the cube of the speed; that is, in the proportion 8 to 1. With the aëroplane the proportion is only 2.4 to 1. This difference in the relation between speed and energy per second is the most important factor that distinguishes the two machines, and you see immediately that the dirigible balloon will not increase its speed very much, even if motors are considerably improved; while the aëroplane will increase its speed largely, and, we may say something more here. We have so far regarded the same aëroplane. Now, we might, of course, choose a different area for different velocities. If I could go further into the theory, I could make it plain to you that in order to go quicker, it would be economical to reduce the area of the aëroplane. If we did not keep the same machine, but designed our machine according to the velocity we want to reach, that would be still more economical, and therefore you may understand that for double the velocity the increase in energy per second is about in the proportion 2 to 1. The energy per second is very nearly proportional to the velocity, if we design our aëroplane accordingly. If motors are improved to give double the energy with the same weight, we may expect that the velocity of aëroplanes will be very nearly doubled, while the velocity of the dirigible balloon would only increase in the proportion $\sqrt[3]{2}$ to 1, or about 26 per cent. The velocity of aëroplanes at the present time is about 50 miles per hour as against about 30 miles per hour of dirigible balloons. If in the future motors could be improved to give double the energy with the same weight, the velocity of aëroplanes would be increased to about 100 miles per hour, while that of dirigible balloons would only rise to about 38 miles per hour. We may there expect that in the future aëroplanes will be vastly faster than dirigible balloons.

But, there is one more point that I should like to present to

you. Physicists are accustomed to the so-called method of dimensions. If they have any machine or apparatus they will say, "If I increase or decrease the dimensions of this apparatus, leaving everything geometrically similar, what will happen, what difference of effect will that introduce?" Let us look at an aëroplane, and let us make the linear dimensions n times as great. Then the surface of the aëroplane would be increased in the proportion of n^2 to 1, and with the same velocity the resistance which is proportional to the area, would be increased also n^2 times. The lifting power, with unaltered velocity, is also proportional to the area; therefore, the lifting force would also be n^2 times as great. Now, the weight of the whole apparatus, if we assume the material to be the same, and everything geometrically similar, would be n^3 times greater. Therefore, you see, if the lifting force in the first instance is able at a certain velocity to sustain the weight, then by increasing the dimensions n times, the lifting force will no longer be able to sustain the weight at the same velocity. To sustain the weight we would have to increase the velocity. And how would we have to increase the velocity? The velocity would have to be increased so that the lifting force becomes n times greater than it was with the larger dimensions and the first velocity. This would be effected by an increase of speed in the proportion $\sqrt{n}$ to 1 as the resistance is proportional to the square of the speed. With this increased speed the lifting power would on the whole be increased n^3 times, and would therefore sustain the increased weight.

Now let us look at the horse power. We can assume the power of a motor to be proportional to its weight. Therefore the power would also increase n^3 times. But this power would not be able to balance the resistance at the higher velocity, for the resistance has increased n^3 times, and at a velocity $\sqrt{n}$ times as great, that would require a power not only n^3 times, but $n^3\sqrt{n}$ times, as great. Therefore our horse power would be too weak to balance the resistance, and the thing would not work. We require motors stronger per unit of weight to carry the enlarged aëroplane. Let us, for instance, increase the dimensions of Mr. Wright's machine twice with the aëronaut in it. Instead of doubling the dimensions of the aëronaut, we can add 7 passengers, which in weight would come to the same thing. Everything is now 8 times as heavy as the corresponding part of the

original machine. Now in order that the lifting power should be 8 times as great, the velocity would have to be increased $\sqrt{2}$ times. But then the resistance would also be 8 times as great, and with the increased velocity would require a power that is not only 8 times, but $8\sqrt{2}$ times as great. This power the increased motor would not be able to furnish, because it is only 8 times as strong. You see that with a certain type of machine we cannot indefinitely increase the dimensions, and with that the number of passengers. We very soon reach a limit beyond which the horse power of the motor will be insufficient. It may therefore safely be said that the number of passengers carried by an aëroplane will always remain small. On the other hand, if we decrease the size, the thing becomes more and more favorable, and that is the reason why small birds fly under far more favorable conditions. I may express it this way, that if the linear dimension is proportional to n, the horse power per unit of weight comes out to be proportional to $\sqrt{n}$. Let us decrease the linear dimensions of Mr. Wright's machine including the aëronaut to one-tenth, then the weight is decreased to one-thousandth. The weight of about 1,000 pounds would come down to about one pound. Then the horse power per pound for this smaller machine would not be the same as the horse power per pound for the large one. It would be less in the proportion $\frac{1}{\sqrt{10}}$; that is, less than one-third. The Wright machine has about 25 horse power to 1,000 pounds of weight; that is, 1/40 horse power per pound. A flying organism of the same type and 1/10 the dimensions would need less than 1/120 horse power per pound.

(The lecturer concluded by showing some lantern slides illustrative of the action of the wind, and of the forms of different aëroplanes.)

SIMPLE EXPERIMENTAL EVIDENCE FOR THE PRESENCE OF IONS.

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The following experiments have been planned for the purpose of demonstrating in a simple manner some of the essential phenomena of the ionization of gases. The needs of the teacher of physics have been kept in mind and the apparatus is in all cases of the very simplest type, including practically nothing outside of the resources of a fairly well-equipped laboratory.

I. CONDUCTIVITY OF GASES FROM FLAMES.

EXPERIMENT 1. Arrange apparatus as in Fig. 1. A and B are two metal plates of any convenient size. (In the experiments here described they were of brass about 10 cm. in diameter supported by clamps on ordinary ring stands). A is grounded through a water pipe; B is insulated from the table

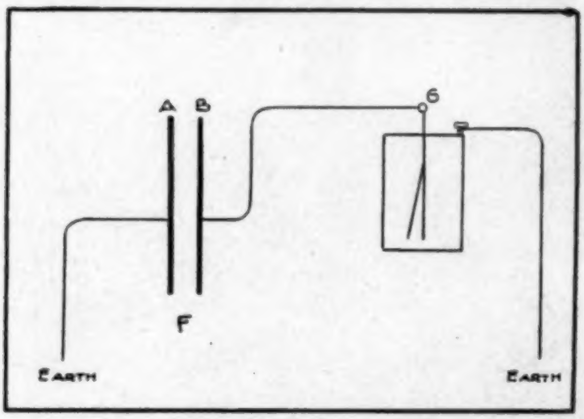

Fig. 1.

by a sheet of hard rubber, and connected by a wire to the knob of a gold-leaf electroscope, G, whose case is also grounded. If a Bunsen flame is held at F, even some distance below the plates, so that the gases from the flame enter the space between the plates, the electroscope, whether positive or negative, will be found to discharge almost as if A and B had been joined by a wire. This discharge will take place even if A and B are more than 15 cms. apart.

Explanation. The gaseous products of combustion have come from the flame in an ionized condition, i. e., some of the mole-

cules have an extra negative electron of which others have therefore been deprived. Suppose plate B to have a negative charge. Plate A, being grounded, will have an induced positive charge. When the ionized gas enters the strong field between the plates essentially the same thing happens as in the electrolytic cell. The positive ions go to plate B, receive from it the electrons of which they are deficient, and so discharge the electroscope; the negative ions go to plate A and give up their electrons. There is thus a true current or transfer of electricity through the gas.

To account for the ionization of the gas we may say that some of the molecules have attained sufficient velocity in the heated gas to disengage an electron, and thus become positive ions. This electron attaches itself to another molecule and so a negative ion is formed. From experiments on the velocity of these ions it is evident that their masses must be greater than that of a single molecule, a fact which is explained on the supposition that an ion may attract to itself several neutral molecules, and thus increase its mass without increasing its charge, the aggregate acting as a single ion.

EXPERIMENT 2. Allow the flame to touch both plates simultaneously. The discharge will be almost instantaneous.

Explanation. Ions are present in large numbers in the flame itself, as the explanation of Exp. 1 suggests.

EXPERIMENT 3. Place flame at side of or even above plates A and B when they are 2 or 3 cms. apart. The discharge still takes place.

Explanation. "The electric field due to the charged conductor drags out of the flame and up to the conductor ions of opposite sign to the charge."[1]

EXPERIMENT 4. Remove plate A altogether and bring flame near plate B. The discharge will take place, but more slowly. The plate is, of course, not necessary, for the electroscope can be discharged by simply bringing the flame near its knob.

Explanation. The slower discharge is accounted for by the fact that the intensity of the field near plate B is not so great as when plate A was present, and therefore the travel of the ions to it is not so rapid.

EXPERIMENT 5. Add to the apparatus shown in Fig. 1 another pair of plates, kept at as large a difference of potential as is available. (In Fig. 2 the arrangement is shown with plates C and D the terminals of a direct current 110 volt circuit.) Have

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[1] J. J. Thomson, "Cond. of Elec. through Gases," p. 229.

plates A and B say 12 mm. and C and D 15 mm. apart. Place flame at F and close enough to plates C and D to prevent heated gases passing to A and B around the outside of the

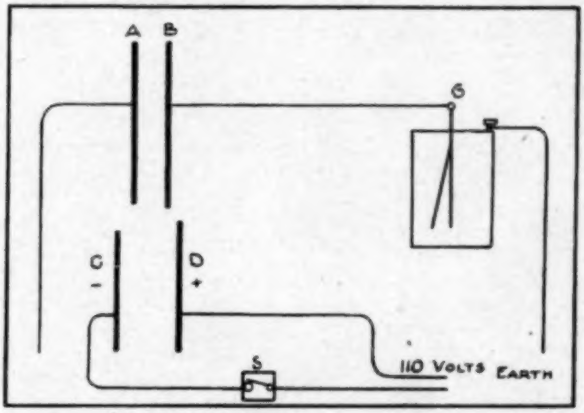

Fig. 2.

two plates. When the switch, S, is open the electroscope will be discharged as in Exp. 1. Close the switch and the fall of the leaves instantly stops. Open the switch and it begins again.[2]

Explanation. The ions from the flame act when between the charged plates C and D just as they did between A and B in Exp. 1. They are therefore withdrawn from the gas, which is then free from ions when it reaches A and B, and so is unable to discharge this pair of plates. That the ions actually complete the circuit and establish a current between the plates will be shown in the next experiment.

EXPERIMENT 6. Place in the circuit of plates C and D and the 110 volt terminals[3] a sensitive galvanometer, G, and a reversing key, K (for use in the next experiment). The arrangement is shown in Fig. 3. Place flame below but not touching the plates. A slight current will be indicated by the galvanometer. Allow flame to touch both plates and a stronger current will result. While the flame is still touching the plates place in it a piece of asbestos which has been soaked in brine, and the conductivity will be much increased.[4]

EXPERIMENT 7. An interesting modification of the above

[2]Results may be obtained by connecting C and D to the knobs of a Toepler-Holtz or other static machine.

[3]With a very sensitive galvanometer results may be obtained with even a single dry cell.

[4]See articles by H. A. Wilson, "Phil. Trans. A," 192, p. 499, 1899; "Phil. Mag.," VI 4, p. 207, 1902.

experiment consists in placing the plates 15 to 20 mm. apart and allowing the flame to fall upon one side only of the space between them. This may be done by placing the burner directly beneath a plate so that the flame is divided and falls part between and part outside of the plates, or by inclining the flame so that it falls on the inner face of one of the plates. Care must be

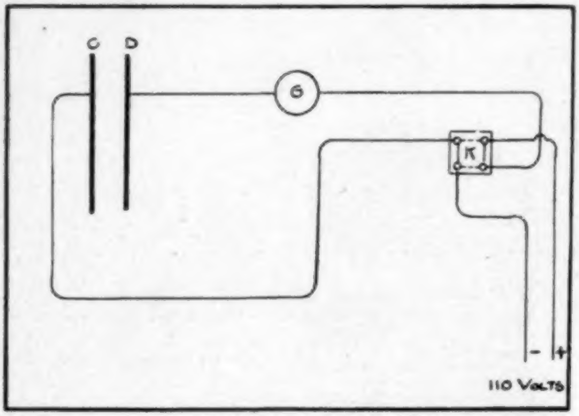

Fig. 3.

taken not to let the flame touch both plates at once. Here we meet with our first evidence of unipolar effects. The current will always be less when the flame is at the positive plate than when it is at the negative plate. Either plate may be made the positive pole by use of the commutator, K (Fig. 3), and the above effect thus be shown to be independent of slight differences in the nature of the plates.

Explanation. When the flame is near one plate the ionization is mostly confined to that region, and the ions of sign like the plate, being repelled, are the ones which carry the current between the plates, the ions of opposite sign being attracted directly to the nearest plate. Our experiment points to the fact that the negative ions are better carriers of electricity than the positive ions.

For an explanation of this fact we must add a hitherto unmentioned difference between the ions. Experiments on their velocity show that in a field of given intensity the negative ions have a velocity several times as great as that of the positive ions.[5] This being true, there will evidently be a greater transfer of electricity

[5] H. A. Wilson, "Phil. Trans. A," 192, p. 499, 1899.

in a given time (i. e., a stronger current) when the negative ions are carriers than when the positive ions carry the current.

II. Ionization by Incandescent Solids.

Experiment 8. Place 2 or 3 cm. of fine platinum[6] wire in series with a storage cell and an adjustable rheostat. Support this wire at a distance of 5 to 10 mm. from the knob of a gold-leaf electroscope. Charge the electroscope negatively and adjust the current until the wire shows a dull red glow. The electroscope will be rapidly discharged. Shut off current and recharge the electroscope. Heat the wire rapidly to brilliant incandescence and the discharge will also be rapid. Repeat these two experiments with a positively charged electroscope and it will be found that the dull red wire has no effect on the charge, while the incandescent wire causes a rapid discharge of the electroscope.

Explanation. The hot wire is evidently giving off ions. When it is red hot only positive ions are given off, while from the white hot wire both positive and negative ions are being discharged. In the latter case the electroscope, whatever its sign, attracts ions of the opposite sign and so becomes discharged, while with the red hot wire and the positively charged electroscope such action is impossible on account of the lack of negative ions.

Note. The emission of positive ions from a red hot wire depends greatly on the previous history of the wire, so that if results are not obtained it may be necessary to take a new wire.[7]

Experiment 9. Support a platinum crucible on its side in a ring-stand clamp. In a clamp on another ring-stand fasten a flat strip of metal. Make the two stands the terminals of a 110 volt circuit in which is included a reversing key and a sensitive galvanometer. Insert the metal strip well within the crucible and make the crucible the negative pole (See Fig. 4). Heat the crucible red hot with a Bunsen flame. No current passes. Reverse the poles and the galvanometer will be deflected an appreciable amount.

Explanation. This result confirms the result obtained above with the red hot wire. There is a tendency to emission of positive ions, which cannot escape from the crucible when it has a negative sign, but which readily carry the current from the crucible to the strip when the sign of the former is positive.

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[6]Fine iron wire will do, but gives trouble by too rapid fusing.
[7]J. J. Thomson, "Cond. of Elec. through Gases," p. 213, ff.

The arrangement of the crucible as suggested above prevents complications from the ionization due to the flame such as would occur if the crucible were placed upright and heated. In our

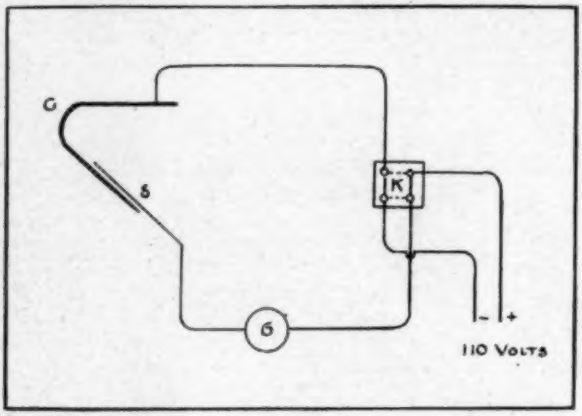


Fig. 4.

experiment the gases from the flame do not come near the strip S.

III. Ionization by Röntgen Rays.

Experiment 10. To show the ionizing power of Röntgen rays arrange apparatus as in Fig. 5. C is a Crookes' tube operated by an induction coil, I, and enclosed in a lead-covered box, L. This box may be open on one side for the insertion of the wires from the secondary of the coil, and should be so large that there can be no discharge from these wires through the lead covering of the box. The lead may be the "tea-lead" used to line the inside of tea chests. Several thicknesses will probably be necessary to act as an effective screen for the rays. At O is an opening through the box opposite the anode at which the Röntgen rays originate. (A one-inch auger hole will do.) Charge a gold-leaf electroscope either positively or negatively and move it about in the region to the right of the box, L. As it comes within the range of the rays which pass through the opening, O, the leaves will rapidly collapse, while outside of this restricted space they will be stationary. (There may be slight motion of the leaves caused by the too close proximity of the induction coil, the imperfect separation of the lead covering from the high potential wires, or the lack of sufficient thickness of lead to totally screen off the rays.)

Explanation. The rays striking on the gas surrounding the knob of the electroscope cause ionization of this gas and the electroscope is discharged exactly as in Exp. 1. The ionization of the gas is probably due to the disengaging of electrons from some of its molecules by the impact of the ether pulses of which the Röntgen rays consist.

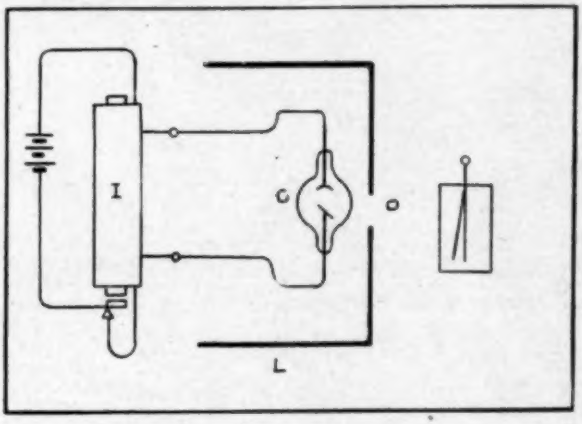


Fig. 5.

EXPERIMENT 11. Place the electroscope outside of the range of the rays from opening O, and by means of a foot-bellows and piece of gas tubing blow air from near the opening against the knob of the electroscope. The discharge readily takes place whether the leaves are charged positively or negatively.

Explanation. This shows that the collapse of the leaves is not due to the direct action of the rays on the electroscope, but that it is the ionized air which causes the discharge.

EXPERIMENT 12. Place a metal cap over the knob of the charged electroscope to protect it from the discharging action. Allow the rays to fall upon the gas inside the electroscope through the glass side of its case. The electroscope becomes discharged.

Explanation. From this experiment it is evident that the Röntgen rays possess ionizing power after passing through several millimeters of glass. This penetrating power of the rays differs greatly with the condition of the Crookes' tube in which they are generated.[8]

EXPERIMENT 13. Replace the knob of the electroscope with a knob enclosed in an air-tight vessel provided with two openings,

[8] J. J. Thomson, "Cond. of Elec. through Gases," p. 644.

as shown in Fig. 6. (For details of construction see Note.) The position of the opening E of the inlet tube T that will give best results should be found by trial, as the success of the experiment seems to depend in great measure on its being properly located. A position about 5 mm. above the top of the knob has given best results with apparatus of the dimensions described in Note. For observing the comparatively slow discharge of the leaves in this and succeeding experiments a micrometer microscope should be used, although a reading telescope focused on a scale placed back of the electroscope will give fairly good satisfaction. The air pump may be a Bunsen filter pump or an ordinary piston air pump. The former gives steady but slow action; the intermittent action of the latter is compensated for by the more noticeable movement of the leaves.

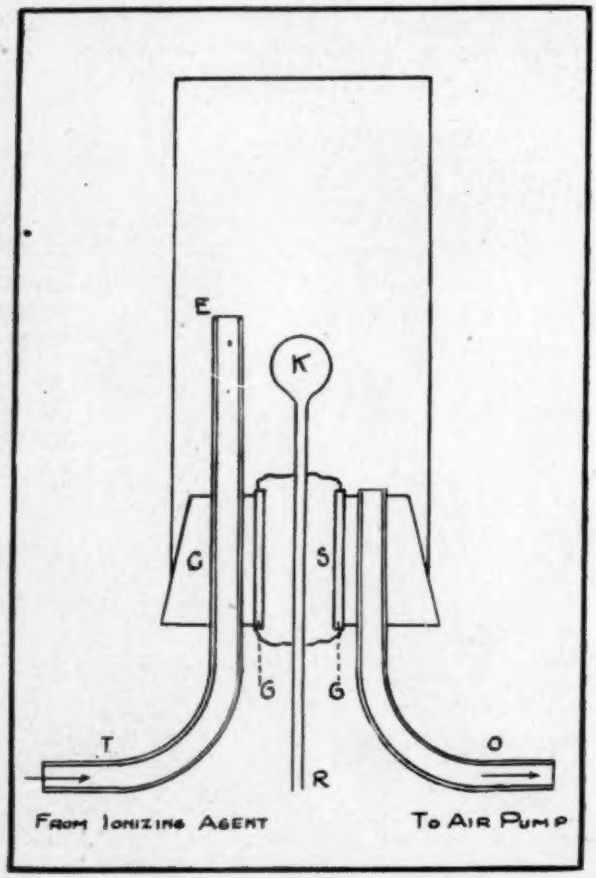


Fig. 6.

To prevent further disturbances of the leaves due to the presence of the induction coil and the wires leading from it to the Crookes' tube, it will be almost absolutely necessary to surround the electroscope with wire netting.

If the inlet tube is too short the electroscope may be affected by X-rays which have penetrated the lead covering of box L, Fig. 5; if too long, the discharge will not be rapid enough. The proper medium must be found by trial. Place the outer end of the tube T in the air which has been acted on by the Röntgen rays and work the air pump. If all precautions mentioned above have been taken, the leaves will slowly fall together.

IV. Ionization by Radio-active Substances.

Experiment 14. Repeat Exps. 1, 3, and 4, using for ionizing agent a small amount of some radio-active substance placed near the plates. In the experiments described a small amount of radium bromide crystallized on a microscope slide was used at first. Later it was found that good results could be obtained by using the "pointer" of a Crookes' spinthariscope. The discharge of the electroscope will be fairly rapid.

Experiment 15. Repeat Exp. 13 with a radio-active substance placed near the mouth of the inlet tube. The discharge takes place as before.

Explanation. The rays given off by the radio-active substance evidently possess the power of ionizing a gas. The nature of these rays it is beyond the scope of the present paper to discuss.

Experiment 16. Repeat Exp. 15 with a small plug of glass wool[9] or even cotton wool in the tube. Make a slight constriction in the tube by heating it in the Bunsen flame and drawing out gently. This will keep the wool from being drawn down the tube. The pump should be worked a little harder to ensure the entrance of air at the same rate as before the insertion of the wool. Notice that the discharge of the leaves is prevented.

The effect may be made more noticeable by suddenly withdrawing the plug of wool and observing the change in the behavior of the leaves. This may easily be done by attaching to the wool a string or fine wire which extends beyond the mouth of the tube.

Explanation. This is one of the best proofs that the ions are *particles* mixed in with the gas, for the action of the wool in

[9] J. J. Thomson and E. Rutherford, "Phil. Mag.," xlii, p. 392, 1896.

this experiment seems to be to filter or strain out these particles from the gas. The same experiment may be performed as a supplement to Exp. 13.

V. Ionization in the Electric Arc.

Experiment 17. Arrange an arc so that one carbon can be readily and quickly removed. This may be done by fastening the carbon in a clamp on a ring-stand. When the arc is in operation remove the incandescent carbon and place it quickly near the knob of a gold-leaf electroscope. The leaves collapse whether the charge is positive or negative. Now allow the carbon to cool to a red glow before bringing it near the electroscope. The negative leaves are discharged; the positive with difficulty or not at all.

Explanation. We have here a case of incandescent solids. See explanation of Exp. 8.

Experiment 18. Blow the gases, as in Exp. 11, from the arc or from its near vicinity toward the electroscope. The same results will be obtained as in Exp. 17. If the arc is blown out and the carbons allowed to cool slowly a time will be found when the gases will not readily discharge a positive charge, but after which the negatively charged leaves will readily collapse.

Experiment 19. Arrange an arc as shown in Fig. 7. A and B are the regular carbons; C is a spare electrode. M is an ammeter of sufficient capacity to measure the entire current flowing through the arc. Put the end of carbon C very close to the opening between A and B. A current of from one-

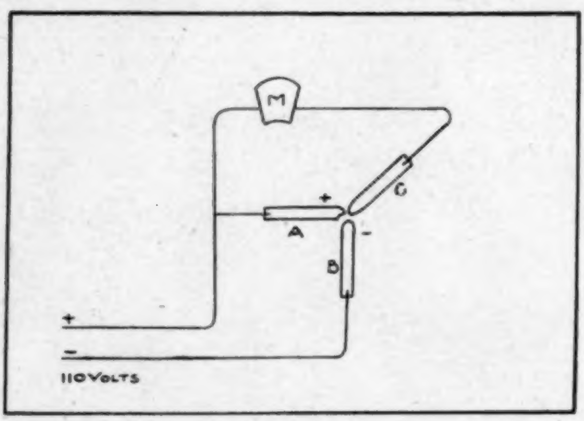


Fig. 7.

twentieth of an ampere, or less, up to the full current of the arc will be registered by the ammeter. This may be shown in a striking way by substituting for the ammeter an electric bell which indicates audibly the presence of the current. If now the carbon C is connected through the ammeter with the negative carbon, B, no appreciable current will be observed. This experiment is due to Fleming.[10]

Explanation. "The cathode is bombarded by * * * positive ions which maintains its temperature at such a high value that negative corpuscles [electrons] come out of the cathode; these, which carry by far the larger part of the arc discharge, bombard the anode and keep it at incandescence; they ionize also * * * the gas or vapor of the metal of which the anode is made, producing in this way the supply of positive ions which keep the cathode hot. It will be seen that the essential feature of the discharge is the hot cathode, as this has to supply the carriers of the greater part of the current in the arc; the anode has in general to be hot, otherwise it could not supply the positive ions which keep the cathode hot; in such a case as that of a third electrode put in the arc and acting as one of the anodes, we may regard the discharge as having two anodes and as one is sufficient to keep the cathode hot we can get the arc to pass to the other anode even although it is cold."[11] When C is connected to the cathode B, it is not hot enough to supply the requisite stream of negative ions.

NOTE.

In making the air-tight vessel of Exp. 13 a metal can about 8 cm. high and 4 cm. in diameter (a talcum-powder can will do) was taken and fitted with a three-hole rubber stopper. One hole of the stopper was about 1 cm. in diameter; the other two were of ordinary size. A piece of glass tubing which would fit snugly into the large hole was cut off to a length somewhat greater than the thickness of the stopper. In one end of this tube was inserted a cork, through the middle of which had been thrust the rod for the extension knob of the electroscope. This rod was now fastened in a vise and melted sulphur poured into the tube until it flowed over the top. The cork was then removed and its space filled with sulphur, which was made to extend beyond the end of the tube. (This collar of sulphur at each

[10] Fleming, "Proc. Roy. Soc." xlvii, p. 123, 1890.
[11] J. J. Thomson, "Cond. of Elec. through Gases," p. 613.

end of the tube will help to keep the sulphur from working loose.)[12] This insulated rod was then inserted into the large hole in the stopper. (See Fig. 6.) The inlet and outlet tubes, T and O, were of ordinary glass tubing, about 4 mm. inside diameter, fitting tightly in the other two holes. To insure tightness the tubes and the edge of the stopper were coated with vaseline.

At the last an ordinary cork with inlet and outlet tubes about twice the cross-section of the first was tried. This seemed to give promise of more rapid results if the cork could be made as air tight as the rubber stopper.

[12] I am indebted to Professor Wm. Strieby of Colorado College for suggestions regarding this method of insulation.

TWO ELECTRICAL THERMOSCOPES.

E. J. RENDTORFF,

Lake Forest Academy.

The various manifestations of heat in physical phenomena are of such importance that a delicate thermoscope for their detection and illustration in the lecture room is highly desirable. Several different instruments intended for this purpose were made and tested before adopting the type of thermoscope described in the December number of SCHOOL SCIENCE AND MATHEMATICS.

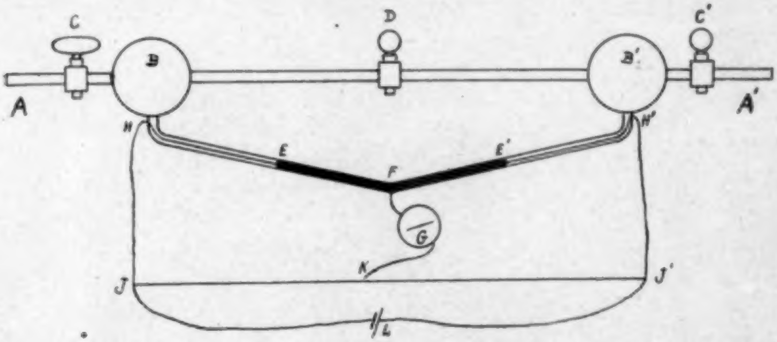
It was at first believed that an electrical thermoscope would be feasible when used with a delicate projection galvanometer. A spot of light reflected on a translucent scale about two meters from the galvanometer was used as an indicator. Two types of instruments were used, one being of unusual sensitiveness, but their adjustment was found quite difficult.

In both instruments the source of heat was applied in accessory bulbs similar to those described in my former article. These bulbs were attached to A or A′ with rubber tubes about 40 cm. long.

In the illustration B and B′ are bulbs about 3 cm. in diameter attached to both an upper and a lower tube. The lower tube is about 2 mm. in internal diameter and has a fine platinum wire running through its entire length. At H, F and H′ are heavier wires leading to a Wheatstone slide wire bridge JJ′. A column

of mercury EE′ fills about one-half of the lower tube. L is a cell, K a contact key, and G a delicate d'Arsonval galvanometer.

With the stop-cocks C, D, and C′ a limited control of the instrument is possible. If an accessory bulb is attached at A and the source of heat is comparatively small, the stop-cock C′



is kept open; with a larger source it is closed; while with an excessive heat the stop-cock D is opened momentarily.

When a reading was to be taken the contact key K was moved along the wire of the Wheatstone bridge until no deflection of the galvanometer resulted. A thermal change in the accessory bulb attached to A moved the mercury column in the lower tube, thus changing the resistance in the two branches HF and FH′ of the bridge. On again depressing the key a deflection of the galvanometer resulted, whose magnitude varied with that of the thermal effect.

In the second instrument the platinum wire through the lower wire was omitted, but the electrodes H, F, and H′ retained. Half of the tube was filled with mercury as before, and the upper ends with an electrolyte. The electrodes H, F, and H′ were connected to the slide wire bridge as in the other instrument.

The objection to this type of thermoscope was its instability, due to its great sensitiveness. When made with a lower tube but a few centimeters long and of very small internal diameter, a high grade galvanometer and an accessory bulb with a rock salt face the instrument should be capable of detecting a temperature change of the order of 1/10,000,000° C.

GRAPHIC RAILROAD TIME-TABLES.

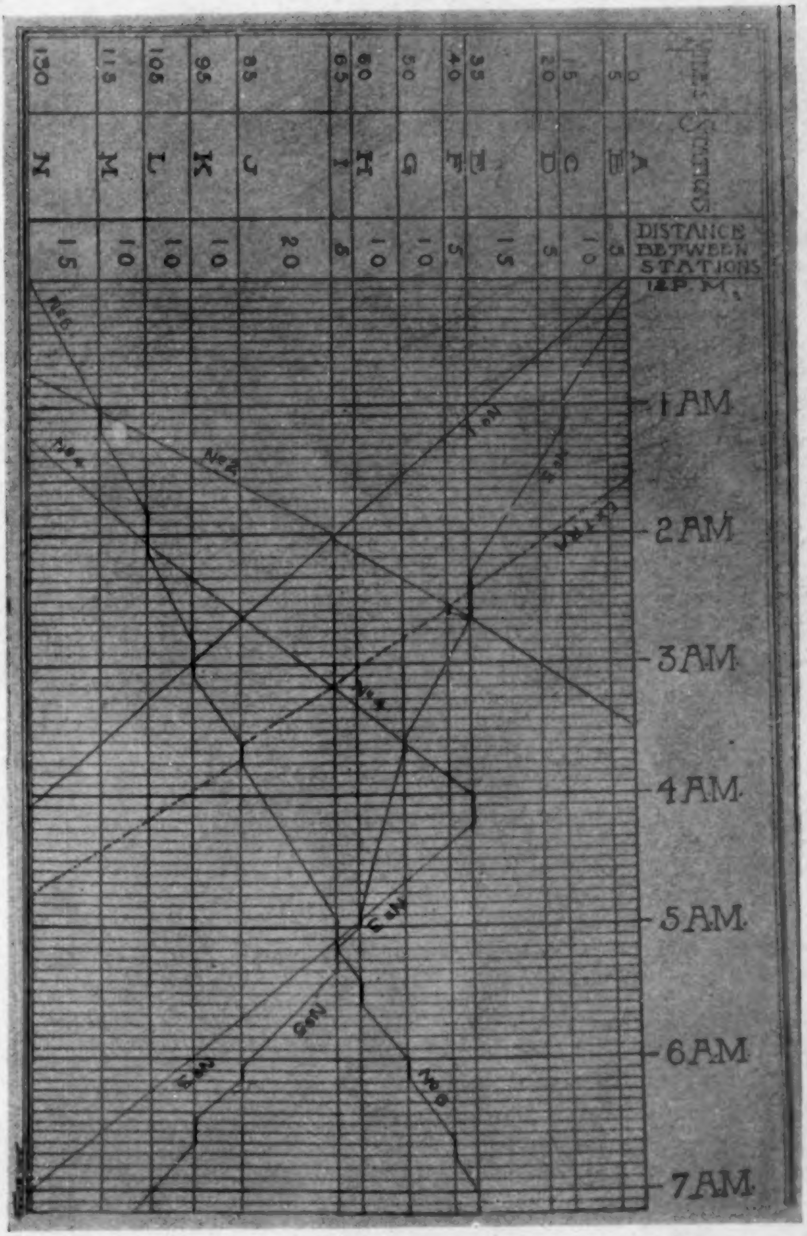
By Florian Cajori,
Colorado College.

A "real applied problem," involving graphic representation, which does not seem beyond the powers of secondary pupils, is the process of constructing railroad time-tables, in vogue in America and also in Europe. I have seen no reference to this in school books, except in Borel-Stäckel's *Arithmetik und Algebra* (Leipzig und Berlin, 1908, page 300). The following diagram, taken from *The American Railway* (New York, Charles Scribner's Sons, 1893, page 161), shows the graphic method of preparing time-tables. The time shown is from midnight until 7 A. M.; each of the small intervals between the vertical lines represents 5 minutes. Horizontal lines at proportionate distances from the top represent the stations, A, B, C, ..., N. The course of every train can now be plotted by oblique lines. Train No. 1, leaving A at 12 midnight, arrives at N at 4:05 A. M. Express No. 2 leaves N at 12:45 and arrives at A at 3:30 A. M. A local train No. 4 leaves N at 1:15, runs to E by 4 A. M., stops there until 4:10 and returns to N by 7 A. M., being called No. 3 on the return. Trains going in one direction are indicated by odd numbers; those going in the opposite direction by even numbers. No. 5 is a way freight; No. 6 is an opposing train of the same character.

The diagram shows at a glance the time when a train arrives at each station, also where the trains meet and pass each other. It is easily seen that the steeper the lines showing the course of a train, the greater is its speed. Horizontal segments indicate stops. If an extra train is to be sent, a line drawn on the diagram will show what opposing trains must be guarded against. "For instance, to send an extra through in three hours, leaving A between 1 and 2 A. M., a trial line will show that Nos. 5, 2, 4, and 6 must all be met or passed, and as (on a single-track road) this can only be done at stations, the extra must leave at 1:35 A. M., pass No. 5 at E, meet No. 2 at F, No. 4 at I, and No. 6 at J. A dotted line on the diagram indicates its run, and that No. 2 is held at F for 5 minutes to let it pass."*

In railroad offices the graphic time charts are prepared first and the time-tables in ordinary use are copied from them.

(*The American Railway, page 162.)


MILES
STATIONS
DISTANCE BETWEEN STATIONS
A
B
C
D
E
F
G
H
I
J
K
L
M
N
12 P.M.
1 AM
2 AM
3 AM
4 AM
5 AM
6 AM
7 AM
EXTRA
No 2
No 6

REPLY TO PAPER BY MR. WHITMAN, VOL. IX, NO. 2 (FEB.), AND BY MR. SPAULDING, VOL. VIII, NO. 8.

By Cora Q. Walker,
Columbus, Miss.

In Mr. Whitman's paper he says, "A girl's world differs, in many ways, from a boy's. The girl has had some of the same experiences, but her world is smaller; she has had less opportunity to observe the commercial physical devices. She is less likely, in future years, to be called upon to run an automobile or a dynamo than a boy is."

Therefore, he urges that instead of giving girls a good high school course in physics, pursued in a rational way, to substitute for it an old-time course in natural philosophy. He suggests cutting out mechanics and giving an overdose on heat; outlining a plan to teach them about the sun being the great source of heat; distribution of heat on the earth; clothing for summer and for winter; freezing water bursting pitchers; ice cream making; and fire extinguishing, as if women are any more likely to serve in the fire department than to run a dynamo.

Children who have studied physical geography and physiology. as all do, might be excused from this course in natural philosophy as they have already covered the ground.

Mr. Spaulding mentions a special case of a girl "with no interest in things scientific, no fund of observational knowledge and no ability to think in mathematical terms, who has tried with most commendable perseverance to remember how to do the various stunts which are likely to be called for in the coming regent's examination. To her they will never be anything but stunts. At first I tried to make them intelligent processes, but they are so remote from the world in which she lives that though she may for a moment catch a glimpse of their significance, it is only for a moment and then only the process remains. What interest can she be expected to have in specific heat, principle of moments * * *?

"The attempt to force her through a course designed for boys in preparation for college is nothing short of a crime. I have said as much both to the girl and her mother, but what can she do? To give up physics is to give up graduating and thus give up the hope of becoming a *teacher.*"

Is it possible that a being so ethereal lives on this old earth?

What right has a person, who has not common sense enough

to master an elementary high school course in physics and mathematics, to become a teacher? How could a person of that mental caliber teach? What instruction can children get from a teacher who has "no ability to think"? To entrust the training of children to such a blank as that would be a crime. It is fortunate for a state that the regents do not let down the examination bars at the demand of every frivolous girl who needs to earn a livelihood. Schools are for the training of the youth of the land and not to give needy people positions.

Following the plans suggested by these champions of female imbecility, a high school course would be minus sciences, minus mathematics, minus history, minus languages, sans everything that might be distasteful to a silly girl or lazy boy.

A person who is incapable of grasping *any subject* of high school grade should give up the ambition of becoming a teacher. Whenever it becomes necessary to make special concessions to persons on account of their feebleness of mind, teaching is not the proper calling for those persons.

But one argument is, since women are "not likely to be called upon to run automobiles and dynamos," girls should not be required to take an elementary course in physics.

Numbers of girls do run automobiles, however. Does every boy who takes high school physics become a chauffeur or a practical electrician? What a *narrow,* low conception of a broad, lofty subject such as physics is, and of physics as a factor in education.

"Education is a broad term. * * * Education is distinct from learning; distinct even from knowledge. * * * Education represents *mental power.* * * * It must pay its due regard to every valuable mental function. In this effort the reason, the perception, and the imagination must be considered. The training of the powers of observation must of necessity lie at the basis of any science teaching. Although it may be true that scientific imagination is one of the most difficult phases of our mental life to cultivate, it need not therefore be neglected. No science is the dull routine of facts that some teachers make it. It has life, vigor, and imaginative color. * * * Our purpose must not be to make our pupils prodigies of science or of learning, but to express how fully the purposes and results of science teaching accord with all that education deems of permanent and vital value. * * * In general, quantitative experiments are always to be preferred to qualitative. The moment a pupil is

asked to measure something, there is demanded a nicety of observation which no amount of qualitative work will bring into play."[1]

"But of physics it can be said that its *reach* is as far, if not farther, than that of any other subject, touching as it does eye, hand, memory, and reasoning powers alike and in a most effective way. I would teach physics for its informational value, for its magnificent training through the laboratory in the systematic doing of things, for its cultivation of the imagination in grasping its beautiful theories, for its usefulness to the individual in the affairs of life, and for the happiness that the knowledge of the 'how' and the 'why' of things about him must confer upon the possessor. * * *

"Cutting out the mathematics will not do it, for the *backbone* is gone; omitting mechanics will not do it, for then explanations of phenomena become largely impossible; dropping quantitative work will not do it, for then the pupil will have no proper appreciation of the way in which the science grows."[2]

"Physics offers especial opportunity for impressing the lesson of scrupulous honesty in observation and statement, and for inculcating habits of accuracy, reliability, conciseness, and orderliness. * * * A physics from which all the difficulties have been removed is a false and a useless physics. * * *

"I have all sympathy with every effort to make high school physics more interesting by making it more intelligible, * * * but let us *beware* that in the effort to make physics popular we do not *confuse instruction* with amusement, the *interest* of *achievement and mastery* with the interest of entertainment, the *satisfactions* of the *student* with the satisfactions of the vaudeville patron."[3]

"It seems but reasonable that an acquaintance with the field of phenomena would give life and zest to later individual experiments * * * and it will also give some *scientific light to that portion* of the *community now left wholly in the dark* in so far as *ordinary scientific concepts* are concerned.

"I advise a *strongly presented* popular course in physics to be given not later than the third year of the high school course, and to be *generally required*. It should *aim to secure* in *girls* as well as in boys a vital interest in physical phenomena and their rational interpretation."[4]

[1]Arthur Dewing
[2]H. N. Chute.
[3]Professor R. A. Millikan.
[4]Lewis B. Avery.

Since physics is a subject which so well subserves the purposes of general education, a subject with scope so great and reach so far, why should girls be deprived of this means of mental development? Why should they not be given an opportunity to develop reasoning power, scientific imagination, powers of observation, and practical common sense? If a girl's life is more circumscribed, and she has less opportunity to learn from practical things than a boy has, that is all the more reason she should have a chance in school to break the shell. She *needs* to study these subjects to broaden her life and give her a vision of greater things.

It is a sad commentary on this age of scientific achievement if the women generally are as ignorant of scientific theories and conceptions as are the women of the most benighted districts of China.

With reference to leaving out mechanics—whenever I have only a half-session to start a class in physics, I give the time to mechanics, and count on their getting the other topics as electives later, as many of them do. I have some pupils (girls) now, who have taken the physics "required," and all of the "elective" physics allowed in their course, and who have been giving from four to six hours per week to physics for this term, although they know that the extra time will not "count" in making up their sixty-five hours for graduation. That indicates an "interest in things scientific."

My observation has been that girls work better for women teachers than for men. I have heard them say, "We shall just tell him we don't understand, and he will take up the whole time explaining it; he loves to hear himself talk, anyway." They soon find out whether they can impose on a teacher or not, and whose work may be neglected with impunity.

I believe if men would be more exacting with the girls in their classes they would come up with better work on physics. At any rate, I don't favor omitting physics from the high school course because girls do not "star" in it, nor of selecting "easy passages" for girls to memorize, and calling it a "physics course for girls." If a girl is mentally incapable of taking an all-round high school course she would make a very feeble teacher.

OLD AND NEW IDEALS IN BIOLOGY TEACHING.[1]

HENRY R. LINVILLE,
Jamaica High School, Jamaica, N. Y.

It is not so very long ago, perhaps less than twenty years, that botany or zoölogy or biology began to be taught extensively in the secondary schools of America. As has been the case with other subjects, the matter and the method made their way down from the colleges. There was no one with the knowledge or the skill to settle the what or the how, because there had been no experience. It was therefore quite natural that the subject-matter known or believed to be important and the method already developed should be used in the teaching of this science in the schools.

Accordingly, the morphological types of animals known to demonstrate the order of evolution in organic development became the subject-matter of zoölogy for the schools. Preserved sea-water sponges, sea-anemones, starfishes, sea-worms, lobsters, etc., began to be shipped in boxes and barrels from Woods Holl and other places where collectors were established to the high schools of the West. The species were not known in the living state to any of the pupils, and probably to few of the teachers. Dissection was the immediate object, and, remotely, the evidences of evolution in complexity of structure.

In botany the type idea was carried out at first with the flowering plants. Detailed studies of tissues developed into the extensive study of the morphology of cryptogams.

The teachers of morphological biology in the schools brought with them from the colleges certain ideas of method. Possibly the lecture system never took strong hold in the schools, but the laboratory method of the college, with much of its paraphernalia, did. The consequence of this was that thousands of young, untrained pupils were required to cut, section, examine, and draw the parts of the dead bodies of unknown and unheard-of animals and plants, and later to reproduce in examinations what they remembered of the facts they had seen.

We who did this kind of business ten or twelve years ago, or do it now, know very well that we never gave, or give, any thought to human interests in connection with our work, partly because most of our college teachers before us seldom thought

[1]Read at the joint session of the American Federation of Teachers and Section L, A. A. A. S. at the Boston Meeting, Dec. 28, 1909.

of the relation to life of their teaching, except in a casual way. As we look back now we may well wonder how we escaped downfall. The only explanation of our escape apparent is that the people were ignorant, and still are, of what we were doing.

Little by little we began to feel the necessity of having a reason for being. We then seized upon the idea that a faculty of observation could be developed and trained, and become useful in life. It was supposed that the habit of looking carefully for details would extend itself to the custom of seeing all things and conditions as they really are. All the time we knew that government clerks and research professors are proverbially stupid in knowing and understanding what is going on outside their spheres. But we kept on until the experimental psychologist spoiled our game by showing that there is no general faculty of observation to be trained.

Before the crisis came, however, we developed the belief that we could get more than mere observation from the pupil. We could get him to think and to form judgments. In this as with observation we counted on the thinking extending itself by a sort of proliferation into spheres outside the laboratory. Not long ago I heard an enthusiast on the morphology of the crayfish declare that if a boy is trained in school to solve the problems of the structure of the crayfish, he will be able to help in the solution of important industrial and financial problems in life. How great our unchecked audacity has become! The psychologists have not bothered us yet in this, but they probably will.

Before the crash comes, why can't we look around and realize on our own account a few things that are true? We know that the method of experimentation, the so-called scientific method, is the process by which the great truths of science have been worked out. Some teachers are beginning to use the methods in the work in biology in the schools, not for the purpose of developing specialists in research, but for the purpose of showing the pupils how problems may arise, how to formulate problems for themselves, how the factors of a problem are analyzed, how the conditions of an experiment must be controlled, what results are, and that conclusions must be based on results. Although the outcome of a class-room experiment may be known to the teacher and possibly to some of the pupils, the method is new and makes a strong appeal on the basis of the fact that it is organized thinking.

Now, we know very well that the practical thinking of our

everyday life is generally not organized; that it is random, haphazard, and without conclusions unaffected by prejudice or other emotion, and frequently not based on accurate data. We also know that the crying need of the times is for men and women who think clearly. The great and splendid opportunity of all the sciences in the schools appears to me to be this: They may use the method of the experiment in school on problems that come up in life itself. A few examples of this sort would be the factors that influence the germination and growth of seeds, the conditions and materials that have to do with the production of food in plants, the preparation and the digestion of food, and the relation of bacteria to health. This would connect the method of the laboratory with the raw material of life, besides helping to organize our careless thinking about life.

In addition to the culture coming from the training, there would result enormous benefit if it brought into a course in biology an entirely new subject-matter. Besides teaching people how to think, we need to teach them how to live. What are some of the ideas a people should have in order to know how to live?

From the living point of view the following topics are unquestionably important:

1. The sources and the biological importance of food.
2. The relation of organisms to man in food production and food destruction.
3. The hygiene of food preparation and food digestion.
4. The use, mechanism, and hygiene of circulation and respiration.
5. Sanitation.
6. The scientific and trustworthy teaching of the effects of alcohol and narcotics.
7. The nature of the risks taken in using patent medicines.
8. Protection-yielding organisms; the sources of clothing and organic building material.
9. The conservation of our natural resources.
10. The usefulness of the beautiful in nature.
11. The organic causes of disease.
12. The conditions of the extermination of disease.
13. The social agencies for the protection of the health and well-being of the race.
14. Sex and sex hygiene.
15. Acquaintance with other organisms in their genetic and ecological relations.

Most biologists will say that this is not biology. It is *not* the subject-matter of conventional biology, but it is the subject-matter of life. And if biology can help along in making human life better and happier in some concrete way, then it can be a useful servant in the education of the people. Otherwise it must continue to be a subject for the laboratory and not for life. This is not an idle pessimistic remark, for the experience of two decades of biology teaching along the conventional lines in the schools has not made it a popular subject. Then, for the sake of the subject as well as for the use to which it may be put, we ought to make it serviceable by finding a basis of classification of the subject-matter which would bring ideas together in logical relation and give evidence that the well-being of human life is the central idea.

This central idea may be expressed in this form:

It is important to know how man in all environments comes into direct and indirect relations with many other organisms, both plants and animals, with non-living things, and with conditions.

The chief divisions of a working syllabus might be:

I. Organisms from which man derives food supplies.
II. Organisms yielding protection and comfort to man's body.
III. Organisms that contribute to the beauty of nature.
IV. Organisms that affect the health of man.

OUTLINE.

I. Organisms from which man derives food-supplies.

(Examples of food from organic sources: meat, milk, butter, cheese, eggs, vegetables, grains, fruit.)

A. The life-history, including the reproduction, of a very limited number of organisms; the physical environment in which they live; living and non-living things in nature.

B. Organisms that exist in relation to those producing human food-supplies; their effect on the quantity of human food as their number may be modified by still other organisms.

1. Organisms that interfere with man's welfare.

a. In field and garden: plant rusts, insects, field-mice and other rodents.

b. In orchards: blights, insects (beetles, bugs, moths), house-flies, etc.

2. Organisms whose activities are useful to man.

a. In field and garden: soil-bacteria, decaying bacteria, earthworms, pollenating insects, insect and rodent, destroying snakes, birds, domestic animals.

b. In orchards: pollenating insects, scale-destroying insects, insect-destroying birds.

c. In houses: bacteria useful in making butter and cheese, spiders, rodent-destroying animals.

C. Methods of preparing and distributing important food-supplies: flour-making, bread-making, fisheries, abattoirs, transportation, merchandise; the division of labor in human society.

D. Government bureaus for the supervision of food preparation. for studying the condition of the production of food-materials, and the reasons for them; pure food laws, meat inspection, bureau of fisheries, reclamation service; the welfare of the whole people.

E. The relation of food to the needs of the human body.

1. Classes of food-stuffs; simple chemical and physical distinctions; how food-stuffs are made in nature.

2. The structure and use of the digestive, circulatory, and the excretory systems.

3. Digestion of foods; chemical tests.

4. The hygiene of digestion and excretion; kinds and amounts of foods, and the conditions under which they should be eaten.

5. Oxidation and respiration.

6. The normal growth of the body; habits that affect it, and how they develop.

II. Organisms yielding protection and comfort to man's body. (Examples of materials: cotton, flax, wood, wool, fur, silk.)

A. The life-history, including the reproduction, of two animals and two plants; silk-worm, sheep, cotton, pine, chestnut, or oak.

B. Organisms and conditions that affect the abundance of protection-yielding organisms: parasites, boll-weevil, clothes-moths, leaf- and wood-eating insects, birds; depredations of man; climatic conditions.

C. Methods by which protection-material is prepared, and the conditions under which the work is done: silk, cotton, fur, wool manufacture; lumber; mills and the workers.

D. Public control of forests: the results of no control; the relation of water supply and lumber supply to protection; how governments are protecting—Germany, Holland, and the United States.

E. Protecting the body.

1. The adaptation of clothes and houses to climate.

2. The relation of clothes and houses to civilization.

3. Necessary and unnecessary clothing; excess of ornamentation; destruction of animals for ornament; waste of wealth.

4. Baths and clean clothing.

5. Ventilation and sanitation of houses.

III. Organisms that contribute to the beauty of nature. (Correlation with teachers of drawing on teaching the beauty of color, line, and form.)

A. The relation of beautiful objects to the happiness of man.

B. The extent of identity of useful objects and beautiful objects in nature: trees and fields of grain; medicinal plants; domestic animals; insects, fishes, birds.

C. The beauty of living things undisturbed in nature: beauty of spring, summer, autumn, winter, day, and night; plants in flower and fruit; birds; man's levy, in a large measure, more customary than necessary.

D. Men may live in the midst of beautiful things in dense communities: public parks; tenements and other houses constructed to admit the presence of plants, with good soil and abundant light and air.

IV. Organisms that affect the health of man.

A. Disease bacteria and the conditions of their existence; tuberculosis, typhoid fever, diphtheria.

B. Animal disease organisms: their life history; malaria, trichina, hookworm.

C. What people can do to exterminate diseases conveyed by organisms.

This outline draws away from the old classification of biological facts and principles, but retains many of the facts and principles in a new classification. Perhaps we shall make greater headway with our problem of how to make biology useful to more people, if we free our minds from the technical bias now so characteristic of professional biologists. Technical points of view, technical abstractions, and technical indifference to popular considerations, have done their unfortunate work in keeping people strangers to the most important factors in their own existence. Permit me to offer this outline as a stimulus for a better and more human order of things in biology teaching.

THE FRACTIONATION OF CRUDE PETROLEUM BY CAPILLARY DIFFUSION.

Experiments Made by the Geological Survey.

The method of refining black vaseline by filtering it through warm, dry fuller's earth suggested to David T. Day, of the United States Geological Survey, that a similar fractional separation of oils might be obtained with crude petroleum. The initial experiment with a sample of green crude petroleum from the "third sand" of Venango County, Pennsylvania, showed that when such crude oil was allowed to filter down through a long glass tube filled with granulated or powdered fuller's earth, light products, chiefly gasoline, appeared first. This experiment was followed by others, and the work was finally taken up, at the suggestion and under the supervision of Mr. Day, by J. Elliott Gilpin and Marshall P. Cram, whose report on the experiments has just been published by the Survey as Bulletin 365. The results are summarized by the authors as follows:

1. When petroleum is allowed to rise in a tube packed with fuller's earth there is a decided fractionation of the oil, the fraction at the top of the tube being of lower specific gravity than that at the bottom.
2. When water is added to fuller's earth which contains petroleum, the oil which is displaced first differs in specific gravity from that which is displaced afterward, when more water is added.
3. When petroleum is allowed to rise in a tube packed with fuller's earth the paraffin hydrocarbons tend to collect in the lightest fraction at the top of the tube and the unsaturated hydrocarbons at the bottom.
4. When oil is mixed with fuller's earth and then displaced with water, about one-third of the oil remains in the earth.—*U. S. Geological Survey.*

AGRICULTURE IN THE HIGH SCHOOL.

By Josiah Main,
Champaign, Ill.

It is the business of secondary education to raise all subjects which it touches to the plane of science, by bringing all into the point of view of organizing principles. E. E Brown, "The Making of Our Middle Schools," p. 4.

Limitation of materials used in nature study, science, and agriculture. Nature-study sets itself no limitations as to the natural materials which it shall use, so long as they are in their natural relations. But little legs cannot carry students of the nature study age very far from home and materials sent from a distance have the defect of being out of their natural setting. From these facts it results that nature-study is environmental and its materials mainly agricultural with suburban or rural pupils.

Biology sets itself no limitations as to the organisms it shall use so long as each is typical of its class and so long as each class is properly but not unduly represented. Some classes are necessarily not represented locally and so we must needs send to Texas for scorpions and to Woods Holl for starfishes. However, convenience and economy as well as utilitarian ideals operate to make biology somewhat environmental in character by the utilization of types that the locality furnishes.

The physical sciences acknowledge no local obligations from the theoretical standpoint since they do not deal with objects or organisms that have any relation to struggle, selection, survival, or environment. But they do have artificial limitations in their application to the arts and industries and in their relative ease or difficulty of demonstration. To overcome these limitations instructors are put to some trouble and schools to considerable expense in order to demonstrate processes and phenomena that are not familiar through experiences of the pupils. However, the increasing applications of principles of chemistry and physics in everyday life and the desire of the most progressive schoolmen to utilize in the laboratory those principles which the pupil may find operating in his environment are making the physical sciences more and more environmental as witness the omission of that phase of physics included under the name of astronomy from the high school courses of to-day.

Agriculture sets itself as a limitation the requirement that in the choice of materials and processes only those having economic importance for good or evil shall be studied. But the rapid de-

velopment of the science and the increasing utilization of species and principles which a former generation would never have thought of as having any agricultural significance compels the student of agriculture, in anticipation of his future needs, to consider more and more matters which belong to the broader fields of science.

The result of these separate tendencies in the separate fields of nature-study, agriculture, and general science is to unify these subjects, and unification in education always means economy. This unification does not apply to the ideals and methods of instruction in these subjects. In fact the closer they are brought together the more determined are the sponsors for each that their separate ideals shall be preserved inviolate and uncompromised. And this is right; nature-study should be strictly cultural, agriculture strictly economic, and science strictly scientific. The value of each depends upon its maintaining its peculiar virtue. On this proposition each of the interests "stands pat" whatever it may demand of the others. Therefore, whatever advantage of unity education may expect of them should be on the basis of their community of interests—the common stock of materials with which they are, or should be concerned.

The true relation of nature-study, science and agriculture.

In the previous development of this nature group of subjects and their pedagogical location in the course, a linear relation of them in the order, cultural, economic, and scientific has been given because, genetically, they succeed one another in that order in individual development and this dictates the order of their presentation in the schools. Culture pertains to the past, economy belongs to the present, and science faces the future. Whatever the dictionary may say, the words carry that significance. Admitting it does not mean that there is any legitimate way of putting culture behind one other than by experiencing it nor that all of the science of the future will always remain in the future. So we put nature-study and the school garden, which belong to the cultural past in the primary and elementary grades, we consider agriculture as it is practiced in the economic present in the grammar grades, and science in the scientific future for which the high school prepares. How then may unity be gotten into a matter that is so marked off and distributed?

It will be noted that in going from the nature-study stage of the lower grades to the agricultural stage of the grammar grades

we do not go to a new and unfamiliar mass of materials but only change our attitude toward the same matters that had before engaged our attention. Similarly, in passing from the economic to the scientific we merely change our attitude. We cannot put off our culture as pioneers following parallels of latitude may have done temporarily in the settlement of this country, only to be pursued and overtaken and bound fast by it, for we are not following parallels of latitude. In assuming the economic attitude we turn at right angles to our former position and face the same materials from a new aspect.

Ordinarily, in the development of a subject it is necessary to have regard for a linear sequence only, though the work may be cumulative and the later stages assume a knowledge of all that has preceded, or at most the change of attitude is gradual. In this subject it seems necessary for the delimitation of the different phases that these changes of aspect be abrupt and at right angles. While it is possible to develop either of these subjects without regard to either of the others, the ideal of an agricultural or scientific education which has regard for a child as a future citizen rather than as a poet, money maker, or scientist must consider the necessity of all three factors. And the educator who is presenting any phase of the subject cannot deal justly with his pupils if he have not an instinctive regard for the previous aspects of his pupils toward the materials with which he is working.

Graphic representation of three dimensions. When a product is made from three factors it may be graphically represented by a rectangular solid, the three dimensions of the solid standing for the three factors. In the nature group the common mass of subject matter may be represented by the solid, its three dimensions being the cultural, the economic, and the scientific factors. This figure implies the essential relationship of the three subjects, nature-study, agriculture, and science, namely, that they are aspects at right angles to each other of a common mass of materials, that taking them in a fixed sequence does not relieve the student or teacher from the necessity of carrying all three factors in mind or such of them as have been previous objects of study (an obligation that the teacher should especially regard), and that proficiency in one does not imply any degree of proficiency in the others.

In the rectangular solid *abcd,* representing the common mass

of materials, let *ab* stand for the scientific dimension, *bc* the economic dimension, and *cd* the cultural dimension, the solid assuming definite shape only as the three organizing factors are applied to it;

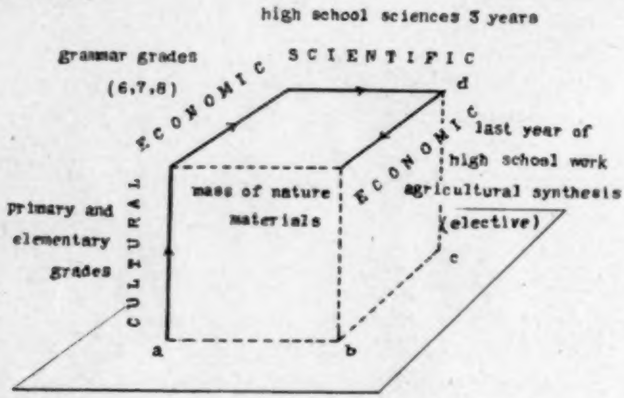


Fig. 1.

To prove that the difficulty that schoolmen have in organizing this material is due to their inability to think in three dimensions.

To be able to teach any subject requires that the teacher have and impart an intelligent attitude toward the subject. For the subject matter to remain in confusion in the teacher's mind means that he cannot teach it to others, so that in viewing the mass, *abcd,* from his cultural standpoint the teacher of nature-study, for instance, instinctively organizes it on the cultural dimension—using the term cultural to signify those needs that are neither present nor anticipated material necessities. What this plan of organization in the case of nature-study should be is a matter that has never gotten into the books and some nature study people insist that it never shall, since no two of them organize it in the same way, and because it is spiritual and embalming properly comes only after the spirit has departed—in other words they do not want the subject killed by organization, thus leaving it to each teacher to organize it according to the needs of each particular case but agreeable to recognized general principles. No further discussion of the organization on the cultural dimension will, therefore, be essayed other than to call attention to the mathematical fact that this dimension is as important to the solid as is either of the others and the educational fact that if it be allowed to diminish to zero the entire volume

becomes zero for educational purposes. It should also be noted that after the nature study stage of development of the child is passed and the economic and scientific stages are in turn brought to the focus of attention the cultural purpose should be incidental.

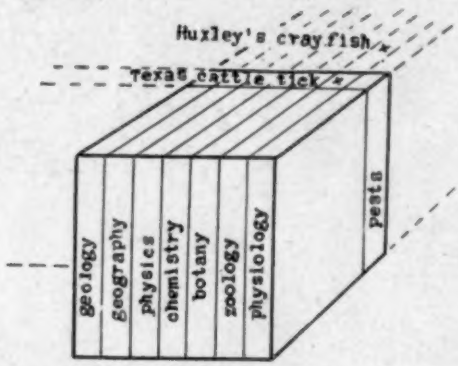


Fig. 2.

When the scientific aspect is approached (Fig. 2) organization is spontaneous and the whole mass crystallizes into perfect laminæ with planes of cleavage at right angles to the scientific dimension in a manner comparable to the behavior of the magnetic needle brought within the influence of a current of electricity. On this aspect each lamina stands for one of the fundamental sciences, botany, zoölogy, chemistry, etc., the laminæ together including the entire mass of the solid.

Coming to the economic aspect (Fig. 3) the making of agriculture a high school subject means its organization on the economic dimension, since no attempt at organization in the grammar grades, before the details are studied analytically as pertaining to the fundamental sciences, can have more than temporary educational value.

This latter economic organization has not yet been completed, some laminæ having been early marked out, as horticulture or animal husbandry, while other plans of cleavage meet with such obstacles in the mass as to warp and bend and obstruct them, and some of the original laminæ showing a tendency to split into numerous subdivisions.

The educational frontier. This is now the educational frontier —the organization of agriculture as a high school subject on its economic dimension after the analytic study of its materials in

the work of the science classes. When so organized we will have a science of agriculture and every portion of the mass of the solid will lie in a distinct economic plane. As it is evident that a complete organization will never be possible owing to the ramifications of certain subjects into other subjects, such, for instance, as the matter of fertility, the conception of agri-

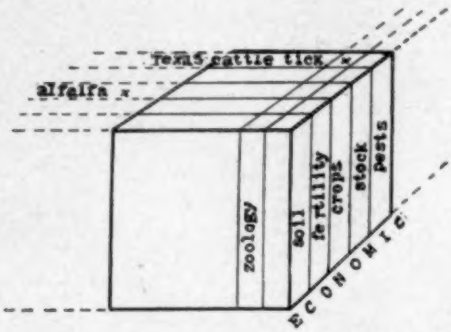


Fig. 3.

culture as a science will always have to be taken with exceptions. This necessity does not obviate that other one of continuing the attempt at organization and science men who are used to the stricter conception of the term "science" may do well to tolerate the other usage. Aristotle must have had some such condition in mind when he said, "It is affectation to try to treat a subject more exactly than its nature permits."

The function of science is organization and it requires that everything else give way to that purpose. The function of agriculture in the schools must be economic and for that purpose organization is to be regarded as a means rather than an end. The love of science may be such as to lead the student to abandon the economic purpose for the scientific at some place where the pursuit of the former leads to a point from which open out attractive fields of scientific study, which is frequently the case with students in the agricultural colleges. It is, therefore, much to be desired that the economic be given its due share of attractiveness in the high school that a portion of its pupils be safely guided from the economic phase of the subject as presented in the grammar grades, through the analytic stages as considered in connection with the high school sciences, to the synthetic treatment in the later part of the high school work.

Bringing materials within the solid for organization. When completely organized, as suggested in previous paragraphs, the place of every fact, principle, and organism is as definitely determined as may be the latitude, longitude and altitude of Mt. McKinley. Thus organized, some things of high value in one aspect will be of low value in another. The art of directing the high school work in agriculture and science is to utilize matter that is of high value in as many different aspects as possible, taking care that such subjects as are of little value for one purpose have their existence in the work justified by a high value for some other purpose. And it will be necessary in the treatment of the different phases of this nature group of materials to utilize in the development of each phase of it certain matters that have no value whatever in the treatment of either one or both of the other phases. Thus Huxley's crayfish, which is a vertebrate turned inside out and upside down and hind end before, stands high in the scientific purpose as a means of distinguishing between the essential and the non-essential in animal structure, as an example of the success of a type of structure that contradicts erroneous ideas that may exist in the student's mind gained from the teachings of the ordinary texts on human anatomy and physiology. Our method of graphic representation would have to indicate such a fact as lying outside the common mass of materials, though still in its proper place in the scientific plane. Similarly, the pussy willow and alfalfa which may rank high in their respective cultural and economic planes may be entirely outside the common mass. In such cases as these, correlation must give way to the needs of the particular subject under consideration. But these exceptions are not so common as teachers of high school science have heretofore seemed to think.

As an example of a compromise that illustrates the matter under consideration no better illustration could be found than *Boophilus annulatus* which, besides being typical of a large class of animals, is valuable scientifically for the study of its life history and as a typical parasite. Other examples may be as good for these purposes but when we discover that *B. annulatus* is none other than the Texas cattle tick that costs the state of Tennessee eleven million dollars annually and the other Southern States correspondingly, such school as may procure this organism may do well to have regard for its economic significance by utilizing it for purely scientific study. Similarly, in the study

of entomology, the corn plant alone furnishes good examples of five of the seven Linnæan orders, all of high economic importance. The same condition exists with regard to botanical types, as noted elsewhere. While advanced students of pure science, to be true to the ideals of their calling, cannot have regard to the economic importance of the forms studied, the high school student of science will have plenty to do well within the economic limitation. On the other hand, the teacher who is committed to the teaching of the "practical" should not fail to appreciate the fact that no organism, however insignificant it may be economically, how rare numerically, or how aberrant structurally, but may help emphasize the essentials of structure of one that has economic significance.

Trouble with that third dimension. Some further features of our rectangular solid are significant. It is evident that one may pass directly from consideration of any aspect of it to the consideration of either of the others, so the student or teacher may pass directly from the consideration of nature study to either science or agriculture or may have an appreciation of the latter two without having any conception of the cultural significance of the total. These possibilities, namely, the three single aspects and the three possible combinations of them, none of which is sufficient, explain the diversity of views on the subject similar to those entertained by the

"six men of Indostan
To learning much inclined,
Who went to see the elephant
(Though all of them were blind).
That each by observation
Might satisfy his mind.

* * * * * *

"And so these men of Indostan
Disputed loud and long,
Each in his own opinion
Exceeding stiff and strong,
Though each was partly in the right,
And all were in the wrong."

Generally that third dimension or its equivalent has been the stumbling block of every form of mental endeavor that calls

for judgment, from the high school student of solid geometry to the landscape painter who "lacks perspective." So general is this defect that the critic of any piece of work may fall back upon it when other criticisms are impossible, though, rightly conceived, it constitutes the finest test of the artistic temperament. And in the case in hand it is a test which many a schoolman fails to pass because he can see only one face of the solid.

Limitations of the nature-study view point. We sometimes see the nature-study people claiming to have the only correct point of view because, as they see it, it is very plain that the whole subject of agriculture may be organized on the cultural dimension, and theirs being the first in point of time, they are loath to yield to anyone else this popular field in which they have had such success in the elementary grades. The progress from the nature-study stage to the complete organization in all three dimensions is a necessary metamorphosis through which some school men seem unable to pass. One who cannot get away from the nature-study stage cannot organize his knowledge as general science however much it accumulates. Organization implies science. Continued work in nature-study may result in the accumulation of a vast mass of interesting materials and the formation of encyclopedias, but its character as nature-study material precludes its unification into science. Its exponents and teachers should not and usually do not expect it to aid in the solution of the problem of high school agriculture. Like Maggy in "Little Dorrit," it is destined to remain forever "just ten." "When I was a child, I spake as a child, I understood as a child, I thought as a child; but when I became a man, I put away childish things."

Inadequacy of the economic view point. We sometimes see the agriculturists claiming to have the only point of view from which to organize this subject of agriculture in the high school and they are a very formidable set of promoters to cope with because they know the strength of the popular dissatisfaction with the high school and that the hopes of its reform are based, to a large degree, on their progress. They also have the art of achieving an early seeming success which they attain by substituting for the citizenship ideal, which is slow of attainment and demonstration, the purely economic purpose which measures the success of their plan by dollars and cents and requires just one season and one crop to demonstrate.

Investigations concerning the doctrine of formal discipline have shown satisfactorily that unless a subject is consciously idealized during the period of training in it, by the enlightened enthusiasm of the teacher, such acquirements in neatness, accuracy, thoroughness, persistency, etc., as it affords the pupil will be of little value to him in the pursuit of other studies or exercises. The value of formal discipline thus inheres in the subject in which the discipline is given and unless the personal virtues exercised in its pursuit are purposely dignified by the teacher such subject is inadequate for the purposes of general education. This fact makes it incumbent upon the teacher who would make agriculture a culture subject, without which its educational value will be limited, to idealize it. Were the purpose merely to impart valuable information and drill in correct practices, the instruction would not call for such idealization. In this matter the work in agriculture in the agricultural school may essentially differ from that of the regular high school whose ideal is the highest type of citizenship. Thus it is that the culture factor must be carried along with the economic to the end of the course and thus it is written that "man shall not live by bread alone."

When the grammar grades have done their whole duty in the teaching of agriculture the only thing left for the high school to do in the matter is to raise it to the rank of a science. This involves the scientific consideration of every feature that is to have a place in the science of agriculture as the high school shall attempt to organize it. *The only technical difficulties in the study of agriculture are scientific difficulties.* This analysis is, therefore, best provided for in the regular science classes of the first three years of the high school course. The advantage to the fundamental sciences of the utilization of agricultural materials is a matter of vital importance to the sciences themselves which will be dealt with elsewhere.

Unless this scientific treatment of such features as are related to the fundamental sciences is done, agriculture can no more become a high school subject than a stream can rise higher than its source, and its extension into the high school will bring discredit upon it as well as upon the high school that attempts it, for no high school student who has average mental powers and the average respect for them will be attracted by a subject that is kept in its elementary stage. But after an analytic treat-

ment of details as a part of the regular science work this subject may be erected into a science by the synthesis of details, previously treated analytically, with the general principles which involve the art of agriculture.

Tyranny of the scientific view point. We sometimes see the scientists claiming to have the only possible system of organization because that is the peculiar function of science—to organize. So much do the cultural and economic organizations suffer from the comparison with the scientific organization that the passage of an economic plane of cleavage, for instance, at right angles to the scientific has the effect of polarizing all the light from that aspect, resulting in diminished lucidity or even extinction. Through such incomprehensible masses as marketing, stock judging, silos, manures, or forage crops, their places of cleavage refuse to cut. Such persons are, of course, not suited to teach the subject of agriculture in its synthetic form as an organized science. And when one considers the application to agricultural purposes and the use of agricultural materials that is intended to be a feature of the work in elementary physics, physical geography, botany, zoölogy, and chemistry, he will be forced to conclude that such insistence on scientific perfection is inconsistent with the use of such subject matter. For in all the high school work the agricultural pabulum must consist largely of "roughage," not only from local necessity but from preference as well, for roughage is a necessary concomitant of the "horse sense" which is a cherished object of agriculture in the high school.

Conclusion. The proposition made at the beginning of this discussion was that the difficulty of schoolmen in dealing with the subject of agriculture in the high school is due to their inability to think in three dimensions. The discussion was intended to suggest the characteristics which constitute the value and the difficulty of each dimension. From these characteristics follow the various defects of teachers of the subject, which will be briefly summarized. For wherever the discussion of this subject of agriculture may begin, it usually ends in a discussion of the qualifications of teachers.

By common consent the necessary preparation for the high school teacher of any subject will include university or collegiate training in his specialty, and this necessity can in no other subject be greater than in the teaching of agriculture. The greatest fault peculiar to such teachers is apt to be the lack of appreciation

of the cultural value of the subject owing to the fact that culture is deep-seated and must antedate the collegiate training of the teacher.

The greatest fault of the scientist will be his inability to gather together into synthetic unity the dissociated bits of the subject, granted that he has done his duty by it in the regular science work preceding its organization. He may also be found unwilling to concede that the knowledge of nature as presented in the high school sciences is more for the purpose of improving on nature than for the formation of a foundation for the superstructure of philosophy.

The disadvantage that the nature-study enthusiast will labor under as a teacher will be his inability to appreciate the whole subject as a high school subject; to realize that no subject has ever gotten into the high school from below; that so long as the race is advancing and "ontogeny recapitulates phylogeny" educationally, subjects will, as heretofore, be handed down from above.

And the greatest fault of the teacher whose principal qualification for the agricultural work is that he was "reared on a farm" is that his stock of agricultural knowledge will usually be found largely composed of things that ought, for the good of agriculture, to have been forgotten long ago.

THE MINNEAPOLIS WILD BOTANIC GARDEN.

By Eloise Butler,
South High School, Minneapolis, Minn.

On account of the rapid growth of the city—spreading out like a spider's web for miles in all directions—and the consequent disappearance of the wild lands and their indigenous vegetation—making it necessary for students of botany to go farther and farther afield for specimens, it occurred to the writer, some years ago, that means should be taken to establish a plant preserve, within which to maintain representatives of the flora of our state; to serve also as a dépot of supplies for the schools; as a resort for the lovers of wild nature; and to afford an opportunity to study botanical problems at first hand.

Accordingly, the teachers of botany in Minneapolis and other interested citizens petitioned the park board to set apart a tract of land for the above named purposes; the teachers were to supervise the garden, the park board were to protect the property and to bear the necessary expenses.

Fig. 1

No site could be more favorable for the aims in view than the one selected. It lies in Glenwood Park, which now comprises about 700 acres, with additions in prospect. The land is of glacial origin and hence abounds in hills, pools and bogs, and has two ponds of fair extent. In autumn, the scene is of surpassing beauty by reason of the lovely groups of trees and the contrasts of color—the vivid reds of the swamp maple and the oaks and the gold of the poplars set off by the white boles of the birch and the dark green foliage of the tamaracks. About seven acres have been given up to the wild garden, which has for its core a tamarack swamp, surrounded by untimbered bog land,

Fig. 2

merging into meadows and wooded slopes. The meadow is threaded by a tiny, tortuous brook, falling through several levels in little, musical cascades. Where it leaves the garden, the brook has been widened by means of a dam into a small pond (Fig. 1) for the harborage of the water lily, nelumbium and other choice aquatics. All the desiderata for plant life are thus provided—abundance of water, protection from cold and drying winds and a rich and varied soil content. A fortunate accident has also furnished a home for sand plants—a quantity of sand, heaped up for the construction of a boulevard having been washed by a storm into a portion of the enclosure.

The tamarack swamp (Fig. 2) is an abiding joy, being the only one within the city limits that has been saved from drainage and devastation for fence posts. Here in the sphagnum the wondrous orchids—the ladies' slippers, and the habernarias—and the strange insectivorous plants—the pitcher plant and the sundew—together with Linnaea, mitreworts, coral root, violets, gold thread, marsh marigold, Indian turnip, bunch berry, cinnamon and shield ferns, mosses, fungi and myriads of other bog dwellers, which cannot flourish elsewhere, are free to disport themselves.

Fig. 3

A paramount idea is to perpetuate in the garden its primeval wildness. All artificial appearances are avoided and plants are to be allowed to grow as they will and without any check except what may be necessary for healthful living. Those in excess may be removed, when others more desirable have been obtained to replace them. Each individual, when procured, is to be given an environment as similar as possible to that from which it came, and then left to take care of itself, as in the wild open, with only the natural fertilizers furnished by decaying vegetation.

Because of the wide variation in conditions (Fig. 3) many plants may be introduced. Stumps and fallen tree trunks are cherished, the former for bird homes and the accommodation of vines, and both for the sustenance of fungi. The place is indeed a paradise for the student of mushrooms, innumerable agarics, geasters, pezizas, boleti, polypori, and huge lycoperdons and lepiotas being found there in their season. The mosses, also, are equally varied and abundant.

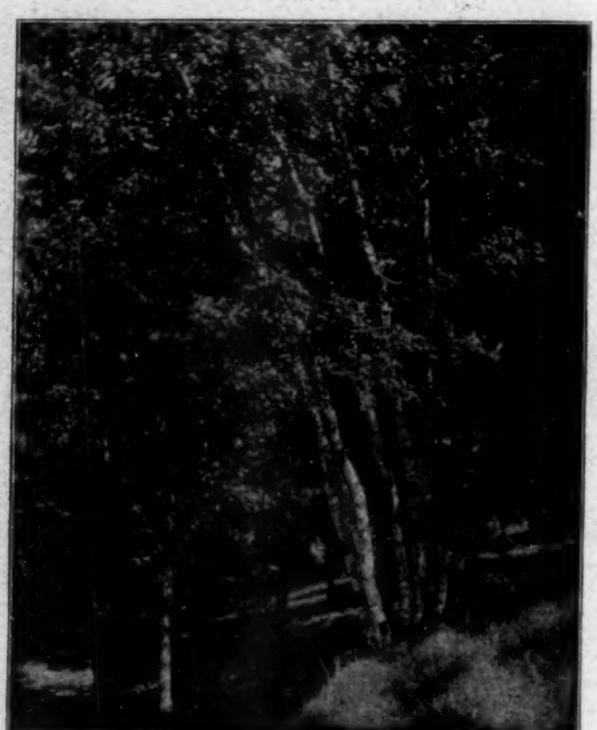


Fig. 4

Of the trees in the swamp, the most frequent, after the tamarack, are the white and the yellow birch (Fig. 4), black ash, red maple and aspen; of the shrubs, cornels, viburnums, willows, dwarf birch, poison sumach and black alder; on the uplands, the red, the scarlet and the white oak, the red and the white elm. Conspicuous among them are a large, beautiful white elm and the largest white oak in Minneapolis (Fig. 5). Twenty species of trees and thirty-six of shrubs are indigenous to the garden. The upland shrubs most in evidence are the staghorn sumach, prickly ash, hazel, wild rose, raspberry, blackberry, hawthorns and the vines—wild grape, Virginia creeper and bitter sweet. It

is proposed to utilize the fence surrounding the garden as a support for all the vines of the state.

The meadow, beside the usual grasses and sedges, is rich in Marchantia, Conocephalus, sundew, grass of Parnassus, tall lobelia, late meadow rue, the Canada lily, the small cranberry, thoroughworts, smilacinas, tufted loosestrife and fringed gentian.

On the treeless portions of the uplands, the prairie plants have

Fig. 5

secured a footing, as golden rods, asters, cone flowers, Heliopsis and sunflowers. A large proportion of our shade plants is found in the rich soil of the wooded slopes. Among them, the most notable introduced members are the dicentras, hepaticas, mandrake, rattlesnake plantain, ginseng, twisted stalk and large-flowered trillium. And as but two or three specimens of bloodroot and showy orchis were found, their numbers have been largely increased. In the swamp, Indian poke, spring beauty, dogtooth violets, Clintonia, cypripediums, twayblades, Arethusa, skunk cabbage, calla, phlox, creeping snowberry, Oxalis Acetosella, Dalibarda, and fringed polygala have taken kindly to adoption. The wayward curves of the brook have been emphasized

by plantings of cardinal flower, forget-me-not and Coreopsis lanceolata and the meadow has been further enriched by sweet flag, vanilla grass, lilies, gentians, Calopogon, Pogonia and hibiscus.

Nowhere else do the maiden hair and interrupted ferns grow more luxuriantly (Fig. 6). These in themselves would well

Fig. 6

repay a visit to the garden. To the ten indigenous ferns have been added twenty-seven others, so that now all the ferns of the state are represented except a few hybrids and some tiny forms, difficult of access, like Cheilanthes, Woodsia Oregana and the fragrant shield fern. We have also all the Minnesotan trees except jack pine and shell-bark hickory. Among the introduced shrubs may be enumerated Carpinus, witch hazel, hop tree, wahoo, Canadian holly, leatherwood, button bush, Labrador tea, bladdernut, mountain and striped maple. In short, during the three years of the garden's existence, three hundred and sixty-five species have been established, under the inviolate rule of admitting only native or naturalized Minnesotan plants.

A record of each species is kept in a card catalogue, to be located by number when the proposed minute topographical survey is completed.

We ardently hope that, adjacent to the wild garden, an artificial botanic garden and arboretum will sometime be instituted, wherein may be cultivated all the plants that can thrive in this climate.

FOOD STORAGE IN THE CENTURY PLANT.

By Geo. D. Fuller,
University of Chicago.

Along with the establishment of public parks and the building of their greenhouses there has come a greater variety of material suitable for study in biology classes. In these parks as well as upon private estates century plants for many years have been becoming increasingly familiar objects. Their easy culture and attractive appearance make them favorites with amateur landscape gardeners, and they are worthy of careful study by the student of botany. Found most abundantly in the arid and semi-arid regions of the southern and western states and in the drier parts of Mexico and Central America, they exemplify a type of plant that has successfully solved the problems of desert life. Their loose rosette habit of growth enables them to obtain an adequate supply of sunlight without exposing an excessive amount of leaf surface to the desiccating winds of the desert. The epidermis is exceedingly thick and scantily supplied with deeply sunken stomata; thus the loss of water by transpiration is reduced to a minimum, while the thickness and length of the leaves afford space for the storage of water and food.

In the best known species, the American century plant, Agave americana, the first years of the plant's life are devoted to the manufacture and storage of food in the form of sugar and mucilage. The period of accumulation varies according to the habitat, ranging from 10 to 30 years in the warm climate of Mexico or tropical America, to 40 to 60 years or even more when the plant is grown in cultivation in cooler regions. Finally a large rosette is developed composed of long and very fleshy leaves full of food for the rapid development of the flower cluster the climax of the plant's activities.

Early in spring an upright stem appears and by midsummer it has attained a height of eight feet or more (Fig. 1). Although this rapid growth is made by calling upon the food reservoirs there is little change in the appearance of the leaves, but as the summer advances there are signs that the reserve is becoming exhausted as the stored food has become transformed into stem and flowers, and as the last flowers expand the leaves become flaccid and empty, no longer able to support their own weight but lying prostrate upon the ground (Fig. 2). The ripening seeds entirely exhaust the remaining energies of the plant and it dies, leaving behind to propagate its

species a number of offshoots from the base of the rosette and the seeds whose production cost the life of the parent plant.

This form of food storage is also of some economic importance as it is the source of two of the national beverages of the Mexicans, pulque and mescal. Several species contribute their store of food to the manufacture of this drink. As the plants approach maturity and are about to send up their aërial flower stem the central bud is cut out leaving a cupshaped depression into which the sap rich in sugar and mucilage flows. This fluid is collected daily and allowed to ferment yielding an alcoholic beverage known as *pulque,* very distasteful to others but much relished by the Mexicans themselves. By distilling the pulque a more highly intoxicating liquor, called mescal, is obtained.

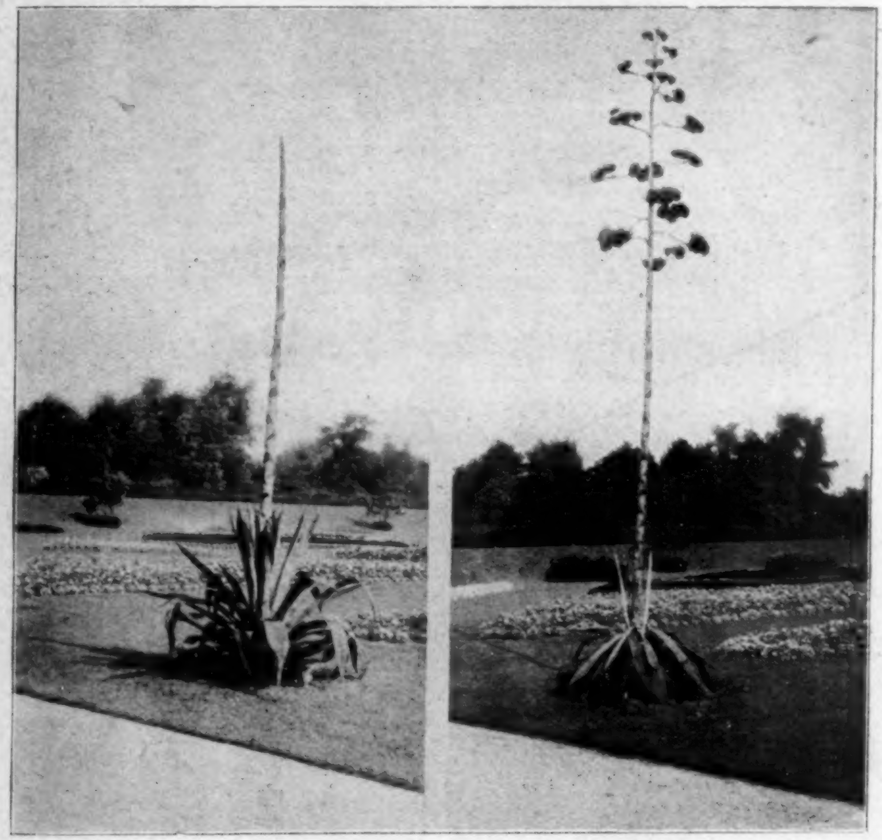


FIGURE I. FIGURE II.

A century plant, Agave Americana, in Washington Park, Chicago, Ill., showing its development July 4, 1907 (Fig. I), and August 31, 1907 (Fig. II).

CONDITIONS UNDER WHICH THE TEACHER OF CHEMISTRY IN HIGH SCHOOLS IS WORKING.*

ALBERT L. SMITH,
Englewood High School, Chicago.

The field that I have tried to cover in this paper comprises that part of the United States west of the Alleghanies, and the facts contained in it are chiefly the results of about 250 letters of inquiry sent to the high school teachers of chemistry during the past month.

For convenience in studying the conditions under which the chemistry teacher is working, the schools from which replies have been received have been divided into the following groups:

1st. Those having 3 or more divisions or classes in chemistry.

2nd. Those having 2 divisions.

3rd. Those having 1 division.

4th. Those having no class this year and those not offering chemistry.

The *first* group includes 67 high schools distributed as follows: Calif. 5, Col. 2, Ill. 10, Ind. 5, Ky. 3, Mich. 5, Minn. 6, Mo. 8, Mont. 1, Neb. 1, O. 11, Tex. 1, Wash. 4, Wis. 5.

The enrollment of these schools varies from that of the Central High School of Detroit with its 2,450 students, 3 teachers and 10 to 12 chemistry classes of 27 each, to that of the Sumner High School of St. Louis with 428 students, 1 teacher and 4 classes of 24 each.

The *second* group includes 53 high schools, of which 1 is in Ala., 3 in Calif., 1 in Col., 1 in Ida., 11 in Ill., 5 in Ind., 2 in Ia., 1 in Kan., 2 in Ky., 5 in Mich., 1 in Mont., 1 in N. D., 11 in O., 1 in Okla., 2 in S. D., 3 in Tex., 1 in Wash., and 2 in Wis. In this group the enrollment varies from the Lane Technical High School, Chicago, not yet two years old, with its 1,517 pupils, 63 taking chemistry, to the West High School of Aurora, Ill., having 240 pupils with 34 taking chemistry. The study is optional in both schools.

With the *third* group, including 65 schools, is found the Higgins High School of Detroit enrolling 55 students, 8 of whom are taking chemistry, the South High School of Manitowoc, Wis., enrolling 70 students, with 12 in the chemistry class, while Davenport, enrolling 800, has a chemistry class of 20, and Wichita, Kan., with an enrollment of 804, has only 11 chemistry pupils.

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*Paper read before the Chemical Education Section of the American Chemical Society, and Section C. of A. A. A. S. at the Boston meeting Dec. 28, 1909.

	GROUP	Required	Req. & Opt.	Optional	Not Answering Question	Total	Av. Number in Class
1	3 or more classes	6	19	33	9	67	22.66
2	2 classes	1	13	31	8	53	18.91
3	1 class	5	10	43	7	65	16.49
	No. of Schools	12	42	107	24	185	

This table shows that in the 185 schools only 12 *require* chemistry, while 42 others require it in certain courses or, in two instances, require one semester and offer a second as optional; 107 make it an optional study, and 24 who offer the subject but failed to answer the question may be fairly supposed to maintain the same ratio.

The average size of the class is greatest (22.66) in the schools having three or more classes, and least (16.49) in those having only one class.

In the *first* group only 13 schools show an average below 20 while 7 have 30 or more per class.

In the *second* group 33 have an average below 20 and only 2 have 30 or more.

In the *third* group 43 have below 20 and 6 have 30 or more.

Fifty-five schools reported chemistry as taught in the third year.

Twenty-six schools reported chemistry as taught in either third or fourth year.

Eighty schools reported chemistry as taught in the fourth year.

The length of the period devoted to chemistry is usually 40 to 45 minutes, in a very few instances 50 and in one case 60 minutes. Of such 40 to 45 minute periods—

27 schools give less than 6, generally 5, per week.

27 schools give six periods per week.

132 schools give more than six periods per week.

Several, as Joliet, Ill., Shortridge of Indianapolis, Muncie, Ind., and some of those in St. Louis and the states of California and Washington give 10 or more of these periods per week to this work.

The teacher in 1 school teaches 8 classes (various subjects).
In 2 schools, 7 classes (various subjects).
In 6 schools, 6 classes (various subjects).
In 39 schools, 5 classes (various subjecte).
In 77 schools, 4 classes (various subjects).

In 53 schools, 3 classes (various subjects).
In 8 schools, 2 classes (various subjects).

The number of hours per week devoted to chemistry classes, outside of school hours, in preparing reagents, apparatus, directions, papers, etc., is as follows:

In 6 schools the teacher gives 25 hours or more.
In 4 schools the teacher gives 20 hours or more.
In 13 schools the teacher gives 15 hours or more.
In 9 schools the teacher gives 10 to 12 hours.
In 40 schools the teacher gives 10 hours.
In 29 schools the teacher gives 5 to 10 hours.
In 31 schools the teacher gives 5 hours.
In 28 schools the teacher gives less than 5 hours.
In 28 schools the teacher did not answer the question.

The 160 answering put in on an average 8.8 hours per week, outside of school hours, in this work for his chemistry classes; besides in many cases having from one to three other laboratory sciences to teach.

Of the 185 schools reporting chemistry classes only 27 report any kind of assistance and most of this from pupils in the class, largely voluntary. A few schools have a regular paid assistant.

As to the nature of the work undertaken, most schools give a one year course of 40 weeks during which the non-metals and more important metals are usually studied. But little time is devoted to organic compounds, although a course of elementary qualitative analysis of 8 to 10 weeks is given in a number of schools.

In most places good modern text-books are in use, but in some, of which Cleveland, Ohio, is an example, a text is in use against which nearly all the chemistry teachers protested.

In many schools the teachers prepare their own list of experiments following more or less closely several of the more recent manuals.

In reply to the question, "Is your work hampered by inadequate equipment?" 55 reply with such answers as, "yes," "decidedly," "some," "somewhat"; 7 of them say "because of lack of room," one, "no, except balances." The other 129 do not seem to be hampered in this manner.

Replying to the question, "What changes in conditions would you suggest to make them more favorable to the best kind of work?" many reply, "more laboratory time," "double laboratory periods," "more free time during school hours to prepare for

laboratory and demonstration work," "fewer subjects to teach," "fewer classes or relief from charge of study room, assembly hall, keeping division records, office work, and athletics."

In conclusion the writer would suggest that—

1st. The chemistry course in our high schools should include at least the equivalent of 7 of the 40 to 45 minute periods per week for 40 weeks and 4 of these periods should be given as 2 of double length.

2nd. A full credit should be given for the study, that is, the 7 periods or more should be regarded as equal in credit for graduation to any five period study, as the languages, history, etc.

3rd. The chemistry teacher should not have more than four classes, of all kinds, to teach and not more than three if he has three different sciences.

4th. The teacher of chemistry should have a least one free period per day for preparing laboratory and demonstration work.

5th. He should be allowed to choose his own text-book.

6th. He should be given an *appropriation regularly* for apparatus and supplies, and allowed to spend it as he thinks best, and turn in itemized vouchers for the same to the proper authorities.

Resolutions Adopted by the Section of Chemical Education of the American Chemical Society at the Boston Meeting, Dec. 27-31, 1909.

Resolved that it is the sense of this section that there is an urgent need for an improvement in the conditions under which chemistry is taught in secondary schools, in the following respects:

1. The time allotted to the subject in the ordinary curriculum is not sufficient and should be increased.
2. The teacher of chemistry should not teach other subjects requiring laboratory preparation.
3. Provision should be made for the preparation and handling of laboratory materials by supplying suitable paid assistants and by allowing the instructor sufficient time each day, during school hours, free from assigned duties, to make such preparation for the laboratory practice.
4. The instructor should be permitted to purchase supplies for current consumption from a petty cash account, or from definite appropriation; his vouchers for the same to be subject to suitable supervision.
5. No text-book should be used without the approval of the teachers of chemistry.
6. A double laboratory period should be considered the equivalent of a single formal recitation.

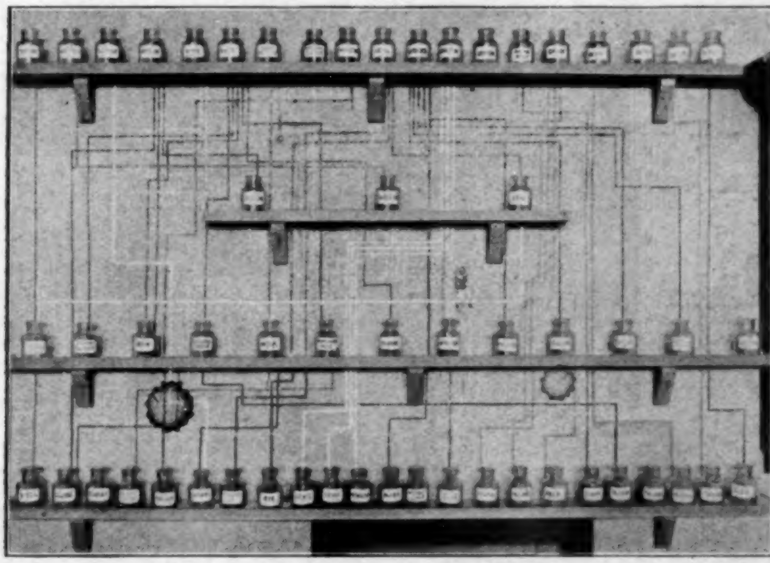
Edward Ellery, Union College, Schenectady, N. Y.
M. D. Sohon, Morris High School, New York City.
Albert L. Smith, Englewood High School, Chicago, Ill.

A SCHEME.

To illustrate the derivation, from the raw materials, of many important commercial substances.

The object is to show by labeled bottles connected by varying colored lines: (1) what substances are derived from a given raw material; (2) what substances are used in making a given manufactured product.

The chart indicates also somewhat: (1) the importance of the original substances; for if a number of lines start from a substance, it means that many others are made from it; (2) the complexity of manufacture; for if a number of lines go to a substance, it means that many materials enter into its composition.



The chart serves as an interesting reference table for pupils in the chemistry class, and arouses interest and attention in outsiders and visitors who like to follow the lines after reading the card of explanation.

When the bottles are filled, the effect and usefulness are increased.

The chart is copied from a similar somewhat larger one in the Deutsches Museum at Munich—a museum very full of practical suggestions to all teachers of science and mathematics and one to which the science magazines have given scant attention.

The chart admits of expansion and variation to correspond to the district, the class, and the facilities.

Top shelf, 5′ 10″ x $3\frac{3}{4}$″; second shelf, 2′ $10\frac{1}{2}$″ x $3\frac{3}{4}$″; third and fourth shelf, 6′ 1″ x $3\frac{3}{4}$″; distance between shelves, 14″.

—*Jessie Caplin, West High School, Minneapolis, Minn.*

A DISCUSSION OF THE REPORT OF THE COMMITTEE ON THE UNIFICATION OF MATHEMATICS.[1]

By H. C. Wright,
J. Sterling Morton High School, Clyde, Ill.

The report of the committee made in the meeting last year I find reasonable, conservative, and admirably expressed. Its suggestions are in harmony with the trend of instruction given in the secondary schools of England and of Germany. And while the movement for unification in the United States progresses slowly, I believe it possesses great things for the high school pupils who enter immediately upon a wage-earning career.

A glance into the mathematical texts of the correspondence schools shows that those alert purveyors of instruction have cut to the quick in their efforts to combine elementary mathematics within the scope of a single work. A bird's-eye view of a subject is a good thing to get. The secondary school pupil should get considerable practice in the fundamental operations of mathematics and some glimpse of the possibilities of the subject. Unification would permit of more time for practice in the technique of the subject and give the pupils an acquaintance with at least four phases of mathematics: arithmetic, algebra, geometry, and trigonometry. Then, too, we must keep out of the way of the psychologists who are asking embarrassing questions about some of the subjects now in the secondary school curriculum. Whatever enables correlation of our work with the other courses in the curriculum makes for added strength in our position. Unification and real problems will give us the means of enriching our material and keeping the work attractive.

Too many studies are taken in the different high school courses for the students to attain precision, suggests Superintendent Ella Flagg Young. Princeton, several years ago, reduced the number of entrance requirements to give opportunity for better preparation in a few subjects. President Lowell in one of his inaugural talks to the students pointed out the desirability of carrying some few subjects throughout the college course. The unification of secondary mathematics would be in harmony with these ideas, for it makes it possible to offer pupils a connected body of

[1]Read before the Mathematics Section of the Central Association of Science and Mathematics Teachers at the University of Chicago, November 27, 1909.

work extending through the four years of the secondary courses. Latin has maintained its prestige partly because there have been offered four years of closely related work in that language in the high schools since their establishment.

I am tempted to give here some of the defense that might be offered for a good deal of satisfaction in the present status of secondary mathematics. Yet when I make the summary there still remains the feeling that one of the most valuable improvements will come through some such unification as the committee has outlined in its proposed four years' course. My teaching experience gives me this feeling. We must advance in our chosen work or lose ground. There is no standing still. But in what can we find satisfaction? It lies in these circumstances, I fancy. The present work is good preparation for the colleges, because the first year reports of many students in college mathematics show high grades. And the patrons of the schools appreciate the fact that their young people are prepared for college entrance either by certificate or through the College Entrance Board. Moreover, the criticism of the business world is directed at arithmetical errors and the work at the present gives much practice in the use of numbers. Texts like the Wheeler, and the Young and Jackson give numerous oral exercises. Then, too, the criticism of the science teachers that the pupils could not solve formulas is admirably cared for in new texts such as the Slaught and Lennes, and the Collins, though most fully treated perhaps by G. W. Evans in a book the publishers dropped because it did not go. We can continue to believe that our subject is of much interest to the pupils, for in our school a study of the enrollment and the number taking mathematics during the last five years shows that although mathematics is an elective study and not required for graduation the mathematics classes have been 54%, 59%, 70%, 63%, and 65%, respectively, of the entire enrollment. The 70% was reached the year that the most courses in mathematics were offered. We can point to decided progress being made towards simplification through the elimination of numerous topics, the addition of a considerable number of concrete problems based on commercial, physical, and geometrical formulas, census data and shop work. Then there is the use of squared paper, colored crayon, the slide rule, and the stereopticon to present different cases in construction problems. And lastly we possess the

illuminating works of David Eugene Smith and J. W. A. Young in their pedagogical and historical writings on mathematics.

But what can be done toward unification by the teacher in the non-technical high school, with the probability of the instructors having to give instruction in one subject other than mathematics, with only the training given the Bachelor of Arts graduate in mathematics ten or twenty years ago and the consequent narrow view of the field, and with the demands of the home and society upon his time, and his efforts to add perhaps to an inadequate salary by tutoring or gardening? It would seem as though such a teacher must depend largely upon the texts offered for his selection.

The old Wentworth, the Fisher and Schwatt, the new Wells, Milne's Academic, the Aley and Rothrock, the Beman and Smith Academic, Myers' First Year Mathematics, and the Young and Jackson have been used as algebraic texts at different times during the past eight years in our school. During the same period six different geometries have been tried. It is evident that great freedom in the selection of texts is allowed some of us mathematics instructors in the secondary schools. Many of us who cannot and should not make the texts, can and do select our books.

The text making must lie with Messrs. Comstock, Slaught, Collins, Hedrick, Myers, Young, Millis and any others whose training has given them a broad view of the subject. Such books as Mr. Myers' First Year Course in Mathematics and his Geometric Exercises bring into a close bond algebraic, geometric, and physical notions and formulas and put into the hands of the ordinary mathematics instructor, material which he can and will gladly present and interpret to his pupils.

Mr. Castle has unified the mathematics of the secondary school somewhat in his Practical Mathematics for Beginners. He uses arithmetic, algebra, geometry, trigonometry, squared paper, and the slide rule in a small volume of a few hundred pages. But the problems are of English significance and not nearly so human as the problems found by Mr. Millis's committee on real problems, or as those Dr. Slaught, Dr. Collins or Dr. Myers so effectively use in their secondary texts. If we are to continue the heuristic rather than the genetic plan of recitation and give out home work, we need texts and readily available sources for problems.

When I used Myers' First Year Mathematics the first year it was offered to the public and had to supplement the book continually by assignments of work in the old style texts in order to give the pupils the amount of discipline it seemed to me that they should have, I found it a task which I was willing to shirk the next year. What I wanted was several times the amount of the same general material. The latest edition of the text in question has about twice the amount of subject matter. The classes that year did pages of the text at a sitting. But I found no supplementary texts.

Just as the College Entrance Board has gradually granted the demands of the teachers in the contributory schools and brought the examinations conducted by the Board to represent the best sense of the body militant among the instructors, so the men of the larger view and the deeper learning have it in their power to give to the lesser lights among the mathematics teachers the fruits of scholarship and to write suitable texts making a close union of that part of elementary mathematics that they consider essential to the secondary schools. The teachers will use such books to the best of their ability, I believe.

In regard to the outlined four years' course offered by the committee, I want to ask that the committee (a) take some current text in geometry and indicate the propositions of small value that they would eliminate in the second year's work in geometry; (b) that in Third and Fourth Year, Part I, they would illustrate by reference to some present text "certain theorems of plane geometry that may have been left for treatment here"; (c) that in solid geometry they would give definite reference to "theorems of small value."

We teachers who have to prepare some pupils all the time for eastern colleges must know definitely what the college considers essential. The head of the mathematics department in one of the largest township high schools in Illinois told me recently that one of his students had been prepared in trigonometry in a text that did not emphasize the matter of radian measure. The boy took the entrance examination in trigonometry at one of the largest eastern universities and three of the five questions involved the use of the radian. That high school now uses a trigonometry written by a professor in the university in question. The instructor cannot afford to be caught that way again. It hurts the prestige of his school. To me the

outline seems wholly feasible. Its scope is within the capacities of the instructors and the time limit allowed for mathematical work. And the proposed unification means economy in presentation of vocabulary, a knitting together of dependent ideas, a constant review of the old material, and a perspective of additional knowledge, and pleasure in the study of mathematics.

DISCUSSION OF THE UNIFICATION OF SECONDARY MATHEMATICS.[1]

By R. L. Short,

Technical High School, Cleveland, Ohio.

The Central Association is getting its bearings. For several years now it has been trying to improve mathematical teaching. Many experiments have been tried; many schemes have failed. But we now see light. The report on unification of mathematics read by Mr. Cobb shows wherein, to a great degree, the real trouble with mathematics lies.

In science work, in all applied mathematics one does not use arithmetic, algebra, geometry, trigonometry. One uses *mathematics.*

Until now we have built up a systematic course in arithmetic; followed this with a somewhat vigorous course in algebra, then came a course in geometry, carefully compiled so that few rules of logic were violated and every rule of pedagogy forgotten.

Throughout each course were glaring sign posts:

"We must not do *this* because *that* has not been proven."

"We must not do *this* because *that* has not been defined."

"We cannot admit this problem in algebra because it is essentially arithmetical."

One of the greatest difficulties arising from the teaching of mathematics in compartments, is that arithmetic and algebra are taught largely as memory and rule of thumb processes, then comes a geometry course that is all thought process, and all three subjects suffer.

I have been asked to discuss our committee's report on unification. Perhaps as satisfactory a discussion as I can offer is a report of what my teachers have accomplished in the past year.

This report offered by the committee is necessarily general in its nature. It is my purpose to give the report my support, show

[1]Read before the Mathematics Section of the Central Association of Science and Mathematics Teachers at the University of Chicago, November 27, 1909.

how some of the details may be worked out, and to urge that the teachers, in so far as they have a free hand in their respective schools, combine quite largely the subjects above mentioned.

It is my good fortune to be in a school where such unification is necessary, essential, desired by those in control, and opportunity offered to try out such courses on pupils from all nationalities and all classes of homes. Such constituency gives the test an exceptional value.

Last year we began this course:

First year, arithmetic and algebra combined.

Second year, arithmetic, algebra, geometry, trigonometry combined.

These combinations were effected by using the regularly adopted texts, rearranging some portions, omitting others and supplementing with mimeograph sheets.

Beginning with our summer quarter, last July, we started a few sections on a combined course of the four subjects, covering a period of two years. We have some 300 boys doing this work.

At the same time we are continuing last year's arrangement in other classes. This affords us a basis for comparison of the two kinds of unification.

We find that it is a success to start with the study of number. We cannot call it arithmetic. The pupil knows all about that subject and is tired of it. We study therefore a new subject—*the composition of number*. Beginning with the digit—the decimal arrangement—and following with the factor phase.

E. g. $17\cdot 6=(10+7)6=60+42=102$.
which is analogous to $(a+b)c$.

When a boy gets $16\cdot 12$ mentally, $116\cdot 12$ does not bother him.

Combine $24=20+4$ with digit problems. If x=ten's digit, y=unit's digit, $10x+y$=the number.

Then the factor phase—of how great value is it?

(1) $6=2\cdot 3$ (2) $6^2=2^2\cdot 3^2$

(3) $12=2^2\cdot 3$ (4) $144=2^4\cdot 3^2$

(5) $(15)^2\cdot(12)=3^2\cdot 5^2\cdot 2^2\cdot 3=2^2\cdot 3^3\cdot 5^2$

(6) $2^2\cdot 3^4\cdot 5$ Compare with a^2b^4c

$2\cdot 3^2$ $a\ b^2$

$2^3\cdot 3^6\cdot 5$ a^3b^6c

I have used no exponent law, but have appealed to the common sense of the pupil.

Oral drill in number makes much algebraic work simple.

During the first twelve weeks we teach oral control of numbers in arithmetic, the four fundamentals of algebra, geometric construction, four theorems, about a dozen originals and simultaneous equations of two and three unknowns.

During the first year our course covers arithmetic, algebra through proportion, all of straight line geometry found in Books I and III.

Second year, the straight line part of Book IV, trigonometry of the right triangle, evolution, quadratics, the curvilinear parts of Books II, III, IV, V.

We make some use of the lever, do something of the proportion of chemistry, and simple problems involving gravity. Much is done toward combining the processes of arithmetic, algebra and geometry.

Compare:

$45 = 3^2 \cdot 5$

$48 = 2^4 \cdot 3$

$54 = 2^4 \cdot 3^3 \cdot 5$

l. c. m. $= 2^4 \cdot 3^3 \cdot 5$

and

$a^2 - 8a + 15 = (a-3)(a-5)$

$a^4 - 81 = (a^2+9)(a+3)(a-3)$

$a^4 - 18a^2 + 81 = (a+3)^2(a-3)^2$

l. c. m. $= (a-3)^2(a-5)(a+3)^2(a^2+9)$

Such examples as this are helpful:

(1) $25x^2 + 30x + 9$ is the area of a square. What is one side?

(2) $x^2 + 8x + 15$ is a rectangle. One side is $x + 3$. What is the other side? Find the dimensions when $x = 1, 2, 3, -1, -2, -3, -5$. Draw each rectangle.

(3) The area of a square is $4x^{\frac{1}{2}} - 12x^{\frac{1}{4}} + 9$. Find the diagonal correct to three decimal places when $x = 16$.

Such work is of course all oral.

Multiplication by factors are useful and helpful when such cases as these arise:

$$81^{.25},\ 216^{.33333},\ 10^{.33333},\ 10^{.301},\ 10^{.4771},\ 10^{.8451},$$

$(10^2)\ (10^{.4771})$, etc.

Thus far the work is most satisfactory. The pupils are interested. They know what they are doing because they think. We do not work by rule. Our entire product is based on principle, axiom, reason.

DISCUSSION OF THE REPORT OF THE COMMITTEE ON REAL APPLIED PROBLEMS IN ALGEBRA AND GEOMETRY.[1]

By G. A. Harper,
New Trier Township High School, Kenilworth, Ill.

In opening the discussion of the report of the committee it is not my intention to attempt to cover the entire report.[2] Neither shall I attempt to limit the discussion to any one particular feature of the report although I shall probably have more to say about its relation to the first year's work of the high school. The work undertaken by this committee is of large proportions; and years of time will be required for the proper readjustment of the high school courses in mathematics to meet the needs and inclinations of the pupils.

Let us examine first one of the hindrances, not with the spirit of belittling the work of the committee but more with a desire to point out some of those things that will have to be overcome. The first hindrance in the way is the present method of teaching algebra in the first year of the high school course. The average pupil enters high school with no knowledge of anything that applies to mathematics except the fundamentals of arithmetic and a very little algebra. He is put to work at once on more algebra and in by far the greater number of high schools, the algebra is almost purely abstract mathematics with very few concrete problems, and those of such a character that less than fifty per cent of the class will be successful in solving them. Generally the concrete problems are written with no other purpose than to illustrate the algebraic principles, and no care whatsoever is taken to add anything to the pupil's store of knowledge by means of the problems. I think it is a safe assertion to make that in at least ninety per cent of the high schools of this country, practically all of the first year's work in mathematics is devoted to the abstract science of algebra, and very little time, if any, is given to anything in the nature of practical applications of the principles that have been learned. It is high time that we turn the process about and teach principles to solve practical problems rather than to continue manufacturing imaginary and puzzling problems to illustrate the abstract principles of algebra. To be sure much has been done during the past decade in the way of getting newer and more practical material

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[1]Read before the mathematics section of the Central Association of Science and Mathematics Teachers, University of Chicago, November 26, 1909.
[2]Printed in the November, 1909, issue of this Journal.

but the change as yet has only affected a few schools and in them not to the extent that is desirable.

The first necessary change, then, is the introduction of more concrete material into the first year's work. The need is by no means as imperative in the other years of the high school course as it is in the first year. The introduction of the real problems must be accompanied by the teaching of such principles as will lead up to these problems. The committee has discovered that the hardest kind of real problems to find are those that require an equation to solve them and are adaptable to first year work. But if we introduce a little geometry and some of the very elementary principles of physics into the first year, then we can find a large number of problems that are practical and can be solved by the aid of equations. There are two conditions though that must be met in these problems; they must be of interest to all the members of the class, and the law that originates the problem must not require as much attention as the law of mathematics that solves it.

There are two advantages to be gained by the introduction of practical, concrete material. One is to arouse and maintain a more lively interest in the work in mathematics and the other is to prepare the pupils for the solution of such problems as they will encounter in their later experiences. Now it is highly imperative that we do everything in our power to secure this first advantage. A few decades ago when geography and history were mere memory studies, and little or nothing was offered in laboratory courses, there was very little need to strive to interest the pupils in mathematics. The truth of the matter is, that it was to many the most interesting of all subjects. But times have changed, so that to-day with the work in manual training, mechanical drawing, domestic science, laboratory courses in botany, physics, and so on, the attractiveness of other things far surpasses that of the same kind of mathematics that was taught a generation ago. Abstract mathematics as a high school study will not be countenanced much longer; it must be combined with those things that are concrete and practical.

The second advantage, I must admit, is a little doubtful to me. I believe there are cases where the artificial problems have more value in preparing the pupil for his later mathematical experiences than the real problems. In all the work that the pupil will be called upon to do in his later school experience, that will

require knowledge of mathematics, he will have about as many artificial problems as real problems to solve. In such studies as analytics, calculus, mechanical and electrical engineering, even physics and chemistry, there are in some texts more artificial exercises than problems based on real experience. No doubt there will be in time a change that will affect these studies as well as the more elementary subjects. But sometimes an artificial problem can be made very interesting; and if it is of such a character that it will give the pupil the proper mathematical experience, I think we would do an injury to neglect it.

There are some kinds of problems and also some parts of the abstract work that we must get away from as quickly as possible. The older texts in algebra take up much space with problems that can be classed as puzzles and nothing else. Take for example one like this: "A boy had a certain number of marbles; he gave away one half of them and found three more; he next gave away one fifth of what he had left and found one more; he then gave away two less than one third of the remainder and discovered that he had 24 marbles left. How many had he at first?" Now such an exercise as that may have its uses. In fact there is very little that has ever been taught under the name of algebra but what may have been of use in some way or other; but the real issue is, is there enough in such a problem to make it worthy of the pupil's time to the exclusion of other material? We could go on and name other parts of the algebra that can be condemned from the standpoint of the most value. There is so much to be taught in the first year of the high school that the teacher can select only those things that are of the greatest interest and the most practical good.

There are some kinds of problems, though not real in the sense that the pupil will meet them in his later experience that, nevertheless, are of much importance. I think we would make a great mistake if we should omit the digit problems, work problems, clock problems, and many others that teach directly the particular features of the equation. If these ideas are accepted, the future courses in algebra will contain much of the work that is done now, but enriched by the addition of a great quantity of concrete material that is drawn from geometry, physics, manual training, mechanical drawing, and so on. To make this work most effective will require the coöperation of the teachers in the other subjects; or what would be better still the coördination of

all these subjects into a single course. If the boy is compelled to use his mathematics to his utmost ability in his work in the other subjects, it will do much to make mathematics a live subject to him. If he solves an algebraic problem in his mathematics class that is obtained from manual training, and never encounters such a problem in his course in manual training, it seems that a part of the stimulus will be lost. But if, on the other hand, the mathematics that he learns in algebra and geometry is continually reënforced in his other courses, much good will certainly result.

It seems that a false impression is conveyed to the pupils, in that they are allowed to believe that after a certain course is completed, they will never have any use for that particular subject again. I haven't very much sympathy for the boy, who, on being told that he had passed his final examination in algebra, replied, "Thank goodness, I am through with algebra at last." Our courses should be so arranged that the work of one course will be carried on to the next throughout the entire educational period of the individual.

In New Trier we have a mathematics club and also a science club. We are planning to hold an occasional union meeting and to discuss subjects that are of interest to the pupils of both divisions. As for example, the subject of the next meeting is, "The uses of algebra and geometry in the study of physics." Perhaps by some plan like this it will be possible to create a greater interest in both subjects.

The committee has divided the real problems into two groups in algebra and three in geometry. It will be very easy to get together any number of problems that are to be solved by substituting in a formula. In many cases the pupils can work out their own formulæ and then apply them by solving many problems to illustrate each one. There are already several texts that give considerable attention to such work as this, and no doubt this class of problems will form a considerable part of the future courses in algebra. A great deal of care will be necessary in selecting the problems that can be solved by equations. A practical problem may interest the members of one class and not those of another. It seems to me that the children in the rural districts who can be interested in problems that pertain to the farms will have the most fruitful source of all. Certainly they have enough varied conditions to offer problems of all kinds.

And the teacher in the rural community will have the advantage over other teachers because all the pupils of her class can be interested in the same problem. Perhaps one or two of these problems are worth reading:

"A farmer starts to cut a field of grain that is 60 by 80 rods, by driving round and round the field. How wide a strip must he make to cut one half of the grain?"

"Where must the clevises be placed in a set of triple-trees for three horses whose strengths are in the ratio of 5, 6, and 7, if the triple-tree is 8 feet long and the double-tree 5 feet long?"

But such problems as these will be of little interest to the city children, and for them a different selection will have to be made. There is one meeting ground, however, for all, and that is the class of problems that combine algebra and geometry. Of all the real problems I think these are the most interesting. I have tried out a number of the problems printed in SCHOOL SCIENCE AND MATHEMATICS and the one that seemed to provoke the greatest interest was the problem asking for the height of a church steeple from similar triangles.

In concluding let me say that the success of this plan lies with the individual teacher. Real problems can be made as dull as any others in the hands of one who is unable to stimulate the interest. Each one of us will have to strive to use those things that will fit the needs of our classes and that we can use most successfully. The future standing of mathematical subjects in the high school courses depends a great deal upon the enthusiasm of the teachers.

PROBLEM DEPARTMENT.

E. L. Brown.

Principal North Side High School, Denver, Colo.

Readers of the magazine are invited to send solutions of the problems in which they are interested. Problems and solutions will be duly credited to their authors. Address all communications to E. L. Brown, 3435 Alcott St., Denver, Colo.

Algebra.

184. *Proposed by H. E. Trefethen, Kent's Hill, Me.*

It is required to resolve the number $2x+y$ into two irrational factors, using the relation $2(a+b)^2+ab=(2a+b)(a+2b)$.

Solution by H. L. McAlister, Arkadelphia, Ark.

If $2x+y=2(a+b)^2+ab=(2a+b)(a+2b)$,

Then $a+b=\sqrt{x}$ and $ab=y$. $\therefore$ $a-b=\sqrt{x-4y}$,

$2a=\sqrt{x}+\sqrt{x-4y}$, and $b=\frac{1}{2}(\sqrt{x}-\sqrt{x-4y})$.

$\therefore$ $2x+y=\frac{1}{4}(3\sqrt{x}+\sqrt{x-4y})(3\sqrt{x}-\sqrt{x-4y})$.

185. *Proposed by W. T. Brewer, Quincy, Ill.*

Within a rectangular garden containing one acre, there is a circular fountain, whose circumference is 40, 28, 52, and 60 yards distant from A, B, C, D, respectively, the four corners of the garden. Find the length and breadth of the garden and the radius of the fountain.

I. Solution by G. B. M. Zerr, Philadelphia, Pa.

Let O be center of fountain, z its radius. Through O draw a line parallel to AB intersecting AD in L and BC in F; also through O draw a line parallel to BC intersecting AB in E and CD in H. Let

$$EO=AL=BF=s,\ OH=LD=FC=w,$$
$$LO=AE=DH=u,\ OF=EB=HC=v.$$

Then $s+w=x$, $u+v=y$. $AO=40+z$, $BO=28+z$, $CO=52+z$, $DO=60+z$.

$$(40+z)^2=s^2+u^2,\ (28+z)^2=s^2+v^2,$$
$$(52+z)^2=w^2+v^2,\ (60+z)^2=w^2+u^2.$$

$\therefore$ $816+24z=u^2-v^2=896+16z$. $\therefore$ $z=10$ yds., radius of fountain.

Then $u^2-v^2=1056$. $\therefore$ $u-v=1056/y$, $u+v=y$, $u=(y^2+1056)/2y$, $v=(y^2-1056)/2y$. Also $w^2-s^2=2400$. $\therefore$ $w-s=2400/x$, $w+s=x$, $w=(x^2+2400)/2x$, $s=(x^2-2400)/2x$, $w^2+u^2=4900$.

$\therefore$ $x^4y^2+x^2y^4-12688x^2y^2+1115136x^2+5760000y^2=0$. But $xy=4840$.

$\therefore$ $x^4-12111.454707x^2+27859400.440608=0$.

$\therefore$ $x^2=9024.3017$ or 3087.1529.

$x=94.949$ or 55.562, $y=50.975$ or 87.11. The second set of values do not apply in this problem.

II. Solution by I. L. Winckler, Cleveland, Ohio.

Use same notation as in Solution I.

Let $BOC=\theta$, $AOD=\phi$, $AD=x$, $CD=y$.

$\overline{OH}^2=(52+z)^2-\overline{CH}^2=(60+z)^2-\overline{HD}^2$

$\therefore$ $\overline{HD}^2-\overline{CH}^2=(60+z)^2-(52+z)^2=16(56+z)$

or $(HD+HC)(HD-HC)=y(HD-HC)=16(56+z)$.

Similarly, $y(AE-BE)=24(34+z)$

$\therefore$ $16(56+z)=24(34+z)$, giving $z=10$.

Also, area $BOC=1178\sin\theta$,

and area $AOD=1750\sin\phi$.

$\therefore$ 1178 sin θ+1750 sin ϕ=2420..................................(1)
Again $x^2=38^2+62^2-2\cdot 38\cdot 62\cos\theta$..................................(2)
and $x^2=50^2+70^2-2\cdot 50\cdot 70\cos\phi$..................................(3)
From (2) and (3) $875\cos\phi-589\cos\theta=264$..................................(4)
From (1) $875\sin\phi+589\sin\theta=1210$..................................(5)
From (4) and (5) $\cos\theta=-0.7929$
Substituting in (2), $x=94.995$, and $\therefore$ $y=50.9$

Geometry.

186. *A sequel to No. 180.*

Points P, Q, R are taken on BC, CA, AB so that $\frac{BP}{PC}=\frac{1}{2}$, $\frac{CQ}{QA}=\frac{2}{3}$, $\frac{AR}{RB}=\frac{3}{4}$; the lines AP, BQ, CR form the triangle LMN; find the ratio of the areas of the triangles LMN and ABC.

I. Solution by Orville Price, Denver, Colo.

Let AP and CR intersect in L, AP and BQ in M, BQ and CR in N.
Let $BP=m\cdot a$, $PC=n\cdot a$, $CQ=r\cdot b$, $QA=s\cdot b$, $AR=p\cdot c$, $RB=g\cdot c$.
Also let PMQC=D, QNRA=E, BRLB=F, ABC=$\triangle$.
From Solution II, Problem 180, we have

$$\frac{D}{\triangle}=\frac{nr(m+s)}{mr+s}.\quad\text{Similarly, }\frac{E}{\triangle}=\frac{ps(g+r)}{rp+g},\text{ and }\frac{F}{\triangle}=\frac{mg(p+n)}{pm+n}.$$

Restoring values of m, n, etc., and adding, we have

$$\frac{D+E+F}{\triangle}=\frac{2269}{2431}.\quad\text{But } D+E+F=\triangle-LMN$$

$$\therefore\ \frac{LMN}{\triangle}=\frac{162}{2431}.$$

II. Solution by G. B. M. Zerr, Philadelphia, Pa.

Take B as origin, BC and BA as axes of x and y respectively.
$(\frac{1}{3}a, 0)$ are the coördinates of P.
$(\frac{3}{5}a, \frac{2}{5}c)$ are the coördinates of Q.
$(0, \frac{4}{7}c)$ are the coördinates of R.
$ay+3cx-ac=0$ is the equation of AP.
$3ay-2cx=0$ is the equation of BQ.
$7ay+4cx-4ac=0$ is the equation of CR.
$(\frac{3}{11}a, \frac{2}{11}c)$ are the coördinates of L.
$(\frac{3}{17}a, \frac{8}{17}c)$ are the coördinates of M.
$(\frac{6}{13}a, \frac{4}{13}c)$ are the coördinates of N.

$$\text{Area LMN}=\frac{162}{2431}\cdot\frac{ac\sin B}{2}=\frac{162}{2431}\text{ABC}$$

$\therefore$ LMN : ABC=162 : 2431.

187. *Proposed by Grace E. Shoe, Denver, Colo.*

ABCD is a quadrilateral; AC, BD its diagonals. If AB$\times$CD+BC$\times$AD=AC$\times$BD, it is required to prove that ABCD is a cyclic quadrilateral. (The converse of Ptolemy's Theorem.)

I. Solution by T. M. Blakslee, Ames, Iowa.

Describe a circle through the points A, B, C. If this circle does not pass through D let it cut BD in D′.

By hypothesis, AD · BC+CD · AB=BD · AC.

By Ptolemy's Theorem, AD′ · BC+CD′ · AB=BD′ · AC.

Therefore $\frac{AD}{AD'} = \frac{CD}{CD'} = \frac{BD}{BD'} = K$.

Hence A and C are on the locus of a point the ratio of whose distances from D and D′ is K. Let M be the point in DD′ such that $\frac{MD}{MD'}=K$. The locus is a circle with diameter MB. If A and C are on the circle, BM=BD′. ∴ D coincides with D′, and ABCD is a cyclic quadrilateral.

II. Solution by I. L. Winckler, Cleveland, O.

Construct angle CDE=ADB, and DCE=ABD. Then triangles DEC and ABD are similar.

∴ CD : CE=BD : AB or CD · AB=BD · CE......................(1)

Also angle BDC=ADE, and from triangles DEC and ABD

CD : DE=BD : AD. ∴ triangles BDC and ADE are similar.

∴ AD : AE=BD : BC, or AD · BC=BD · AE......................(2)

From (1) and (2) by addition

AB · CD+AD · BC=BD(CE+AE) ....(3)

From (3) and the given equation

AC=CE+AE. ∴ E is on AC.

∴ angle DCA=ABD and a circle through A, B, and D passes through C.

Therefore ABCD is inscriptible.

Query by T. M. Blakslee, Ames, Iowa.

Would a proof of No. 175 by No. 164 be "by elementary geometry"? If so, regarding EFGH as a circumscribed hexagon, first as EFBGHA′ then as EB′FGAH, it follows at once that AB′, BA′, EG and HF are concurrent.

What is meant by "a proof by elementary geometry"?

Trigonometry.

188. *Selected.*

In any quadrilateral whose sides are a, b, c, d, prove that

$$d^2=a^2+b^2+c^2-2bc\cos\widehat{bc}-2ca\cos\widehat{ca}-2ab\cos\widehat{ab}$$

where $\widehat{bc}$ denotes the angle between the sides b and c.

I. Solution by Max A. Plumb, Berkeley, Cal.

In the quadrilateral ABCD let AB=b, BC=c, CD=d, DA=a. Let DA and CB produced intersect in E. Let AE=m, BE=n.

$$b^2+c^2-2bc\cos\widehat{bc}=\overline{AC}^2=m^2+(n+c)^2-2m(n+c)\cos\widehat{ac}.$$

$$\therefore (n+c)^2=b^2+c^2-2bc\cos\widehat{bc}-m^2+2m(n+c)\cos\widehat{ac}.\ldots\ldots\ldots\ldots(1)$$

$$a^2+b^2-2ab\cos\widehat{ab}=\overline{DB}^2=n^2+(m+a)^2-2n(m+a)\cos\widehat{ac}$$

$$\therefore (m+a)^2=a^2+b^2-2ab\cos\widehat{ab}-n^2+2n(m+a)\cos\widehat{ac}.\ldots\ldots\ldots\ldots(2)$$

Now $d^2=(m+a)^2+(n+c)^2-2(m+a)(n+c)\cos\widehat{ac}$..............(3)

Substituting (1) and (2) in (3), we have

$$d^2=a^2+b+c^2-2bc\cos\widehat{bc}-2ab\cos\widehat{ab}+[b^2-m^2-n^2+2n(m+a)\cos\widehat{ac}$$
$$+2m(n+c)\cos\widehat{ac}-2(m+a)(n+c)\cos\widehat{ac}].$$

Since $b^2=m^2+n^2-2mn\cos\widehat{ac}$, the expression within brackets is easily reduced to $-2ac\cos\widehat{ac}$. Hence the given relation is established.

II. Solution by Walter L. Brown, Albion, N. Y.

In figure of Solution I let BM and CN be perpendicular to DE, and BL be perpendicular to CN.

Then $b^2=\overline{BM}^2+\overline{MA}^2=\overline{LN}^2+\overline{MA}^2=$

$$(d\sin\widehat{da}-c\cos\widehat{ac})^2+(c\cos\widehat{ac}+d\cos\widehat{da}-a)^2=$$

$$a^2+c^2+d^2-2ac\cos\widehat{ac}-2ad\cos\widehat{ad}+2cd(\cos\widehat{ac}\cos\widehat{da}-\sin\widehat{ac}\sin\widehat{da})$$

But $\cos\widehat{ac}\cos\widehat{da}-\sin\widehat{ac}\sin\widehat{da}=\cos(\widehat{ac}+\widehat{ad})=\cos(\pi-\widehat{cd})=-\cos\widehat{cd}$.

$$\therefore\ b^2=a^2+c^2+d^2-2ac\cos\widehat{ac}-2ad\cos\widehat{ad}-2cd\cos\widehat{cd}.$$

APPLIED MATHEMATICS.

189. *Proposed by H. E. Trefethen, Kent's Hill, Me.*

To what depth does a log 20 inches in diameter sink in water, the specific gravity of the wood to the water being as 70 to 100?

Solutions by the Proposer.

I. The log sinks to such depth that three tenths of the area of the cross section at each end is above water. Three tenths of the area of a circle 1 inch in diameter = 0.2356. In a table of segments with this area for argument we find the height of the segment = 0.3402. $20(1-0.3402)=13.1960$ in. = the required depth.

II. Let O be the center and AB the water line on one end. Put r = the radius and x = the arc AB. Then area of sector AOB = $\frac{1}{2}r^2x$ and area of triangle AOB = $\frac{1}{2}r^2\sin x$. Hence $\frac{1}{2}r^2x-\frac{1}{2}r^2\sin x$ $=0.3\pi r^2$. $\therefore\ x-\sin x=0.6\pi$ ....(1)

Put $x=f+z$, f being an arc taken as near to the value of x as may be. Then $\sin x=\sin(f+z)=\sin f\cos z+\cos f\sin z$. $\sin z=z-\frac{z^3}{3!}+$ etc. $\cos z=1-\frac{z^2}{2}+\frac{z^4}{4!}-$ etc. If $f=135°$, $\sin f=-\cos f=\sqrt{\frac{1}{2}}=k$. Substitute for $\sin x$ in (1). Then $z(1+k)+\frac{kz^2}{2}-\frac{kz^3}{3!}-\frac{kz^4}{4!}=0.6\pi-f+k$, and $z^4+4z^3-12z^2-57.941z+8.0056=0$. Whence $z=0.1346=7°\ 42'\ 41''$. $f+z=142°\ 42'\ 41''=x$. $10+10\cos(x/2)=13.20$ in. = depth as required.

Credit for Solutions Received.

Algebra 178. M. H. Pearson, Orval D. Tyner. (2)
Algebra 179. M. H. Pearson. (1)
Geometry 181. M. H. Pearson, Orval D. Tyner. (2)
Algebra 184. T. M. Blakslee, Walter L. Brown, H. L. McAlister, H. G. McCann, Orville Price, H. E. Trefethen, I. L. Winckler, G. B. M. Zerr. (8)

Algebra 185. T. M. Blakslee, W. F. Brewer, Walter L. Brown, I. L. Winckler, G. B. M. Zerr. (5)

Geometry 186. Walter L. Brown, Orville Price, I. L. Winckler, G. B. M. Zerr. (4)

Geometry 187. T. M. Blakslee, Walter L. Brown, Orville Price, I. L. Winckler, G. B. M. Zerr. (5)

Trigonometry 188. T. M. Blakslee, Max A. Plumb, Orville Price, I. L. Winckler, G. B. M. Zerr. (5)

Applied Mathematics 189. T. M. Blakslee, Walter L. Brown, H. E. Trefethen, I. L. Winckler, G. B. M. Zerr. (5)

Total number of solutions, 37.

PROBLEMS FOR SOLUTION.

Algebra.

195. *Proposed by Franklin T. Jones, Cleveland, O.*

In the scale of 9 a certain number is represented by 13506. Express the same number in the scale of 4. (From a Harvard examination in advanced algebra.)

196. *Proposed by H. L. McAlister, Arkadelphia, Ark.*

In how many ways can 7 pears, 5 apples, and 4 oranges be given to 16 children, each child to receive a piece of fruit.

197. *Proposed by H. E. Trefethen, Kent's Hill, Me.*

Two men travel by day in the same direction round and round an island, 20 miles in circumference, and camp at night. A has two miles the start and goes three miles a day uniformly. B goes one mile the first day, two the second and so on, increasing his rate one mile each day. When do they first camp together?

Geometry.

198. *Selected.*

Let ABCD be a cyclic quadrilateral, having AB=a, BC=b, CD=c, DA=d, AC=p, BD=q.

Prove: (1) $\dfrac{p}{q}=\dfrac{ad+bc}{ab+cd}$;

(2) $p^2=\dfrac{(ac+bd)(ad+bc)}{ab+cd}$, and $q^2=\dfrac{(ac+bd)(ab+cd)}{ad+bc}$.

199. *Proposed by I. L. Winckler, Cleveland, O.*

If ABCD is a cyclic quadrilateral, prove that the centers of the circles inscribed in triangles ABC, BCD, CDA, DAB are the vertices of a rectangle.

Trigonometry.

200. *Selected.*

From $a/\sin A=b/\sin B=c/\sin C$, derive $a^2=b^2+c^2-2bc\cos A$.

REAL APPLIED PROBLEMS IN ALGEBRA AND GEOMETRY.

COMMITTEE ON INVESTIGATION: JAMES F. MILLIS, *Chairman, Francis W. Parker School, Chicago;* JOS. V. COLLINS, *State Normal School, Stevens Point, Wis.;* C. I. PALMER, *Armour Institute of Technology, Chicago;* E. FISKE ALLEN, *Teachers College, New York, N. Y.;* A. A. DODD, *Manual Training High School, Kansas City, Mo.*

Teachers of mathematics who are interested in the movement to reform the teaching of mathematics in secondary schools by teaching the subjects more in relation to their practical uses are earnestly requested to coöperate with this committee *(1) by contributing real applied problems in algebra and geometry to be printed in these columns, where they will be accessible to all teachers for class room use, and (2) by using the problem material here printed in the class room with a view to determining its adaptability to the interests and needs of secondary school pupils.*

For the convenience of teachers who wish to use them, the problems printed in SCHOOL SCIENCE AND MATHEMATICS up to November, 1909, have been rearranged and grouped according to the topics of algebra or the books of geometry under which they come, and bound into a pamphlet, so that a copy may be placed into the hands of each pupil. These pamphlets may be secured from the Secretary of the Mathematics Section, Miss Mabel Sykes, Bowen High School, Chicago, Ill., in any quantity, at 5c a copy.

Problems.

By John C. Packard, High School, Brookline, Mass.

1. A note-book is thirteen inches wide. It is required to divide the page of the note-book into seven columns of equal width. Show how this may be done by use of a straightedge and a pair of compasses, or by use of a ruler divided into inches only.

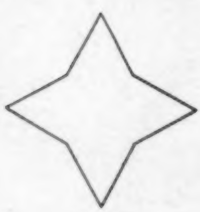


FIG. 1

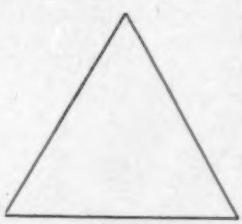


FIG. 2

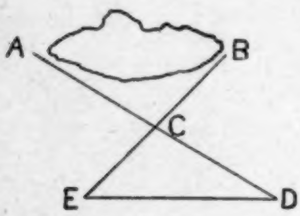
2. Construct a design for a window having an area equal to that of Fig. 2 but shaped like Fig. 1. Draw to scale.

3. The drawing represents the cross section of a ball safety valve. Steam rising through pipe A escapes through B by lifting the ball (sphere) C. The space around C in pipe B where ball has been forced up into the straight pipe must equal space (cross section) across pipe A. Compute the diameter of B if the diameter of A is $\frac{1}{8}$ inch and the diameter of C $\frac{1}{4}$ inch.

How many pounds per square inch is represented by the lifting of C if the ball weighs 0.28 lb. to the cubic inch?

By Clarence E. Comstock, Bradley Polytechnic Institute, Peoria, Ill.

4. It is desired to find the distance between two points between which it is impossible to draw a tape, such as across a small lake, or between two points on opposite sides of a house.

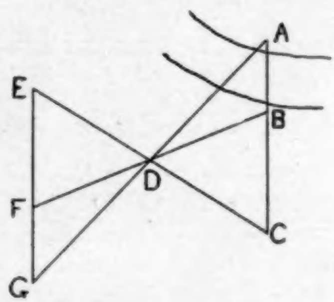


The required distance may be found by the use of congruent triangles.

Let A and B be the two points. Take a point C from which both A and B can be reached. Measure AC. Extend AC to D making CD = AC. So also measure BC, and extend BC to E making CE = BC. Measure DE. This will give the required distance from A to B. Why?

5. Apply the method of Problem 4 in finding the distance between two such points as A and B in or about your own school building.

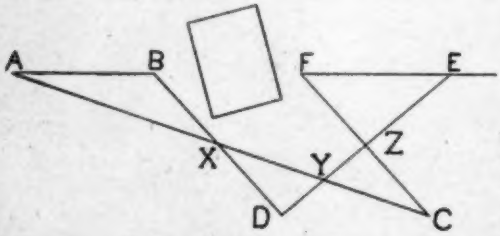
6. Let it be required to find the distance across a river. Proceed thus.



Let A and B be two points on opposite sides of the river. Set a stake at C in line with A and B, BC being any convenient distance. Take D any point from which A, B, and C can be seen, making DB any convenient distance. Set F in line with DB making DF = DB. In same manner make DE = DC. Set G in line with EF and AD. Measure FG. It is the required distance. Why?

7. What changes can be made in the constructions of Problems 4 and 5 if we have the theory of similar triangles at our command?

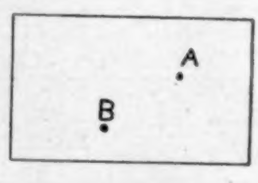
8. To prolong a line through an obstacle and to measure the distance along the line through the obstacle.



A and B are two points on the given line. Take X any point. Measure AX. Take XC = AX and in line with AX. Mark Y the mid point of XC. Make DX = BX and in line with BX. Make ZY = YD. Make ZE = ZD and in line with ZD. Make ZF = ZC and in line with ZC.

Prove FE in line with AB.

What line of the figure equals BF?

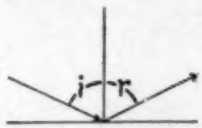


9. It is desired to make the billiard ball B hit the cushion once before it hits the ball A. Determine the point on the cushion.

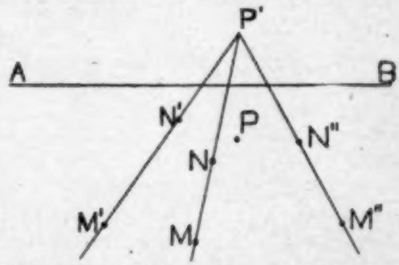
It is desired to make the ball B hit the

cushion twice before hitting the ball A. Determine the point on the cushion.

10. In physics it is shown that a ray of light striking a mirror is reflected in a line making an angle with the normal equal to the angle of the striking ray. That is, $i = r$.

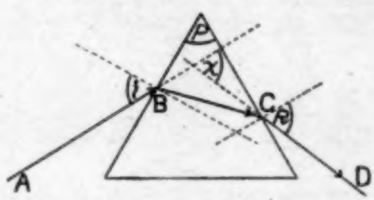


If a mirror is placed perpendicular to the plane of the paper, show that the line of intersection of mirror and paper is an axis of symmetry for any figure in the plane and its reflection in the mirror.



NOTE. The actual determination of the image of a point by the use of a mirror is helpful. Proceed as follows:

AB is the mirror, and P the point whose image is sought (a black-headed pin). Stick pins at N and M so that N, M and image P′ of P are in a line. Repeat three times so as to make a nice determination of P′. Then prove P′ and P symmetric with respect to AB, assuming, of course, that $i = r$ in each case.

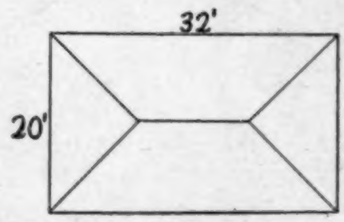


11. The path of a ray of light before and after entering a glass prism is given by the lines AB and CD.

Prove $x = i + R - P$.

Angle x is the deflection of a ray of light in passing through a prism.

This is a good exercise for the student to trace out with the actual prism.



12. This is the plan of the roof of a house. The slope of the roof is 30°. Find the area.

By C. I. Palmer, Armour Institute of Technology, Chicago, Ill.

13. An endless knife runs on pulleys 48″ in diameter at a rate of 180 revolutions per minute. If the pulleys are decreased 18″ in diameter, how many revolutions per minute will they have to make to keep the knife traveling at the same speed?

14. If a tank 5′ in diameter and 10′ deep holds 10,000 pounds of lard, what will be the depth of a tank of 2,000 pounds capacity if its diameter is 3′? If this tank has a jacket around it on bottom and side 3″ from the surface of the tank, how many gallons of water will the space between the jacket and tank hold?

15. A cylinder for cooling lard is 4′ in diameter and 9′ long, and makes 4 revolutions per minute. The hot lard covers the surface ⅛″

deep. How many pounds of lard will it cool in one hour if the specific gravity of lard is .9?

16. If Q denotes the quantity of water passing over a V-shaped notch per second, and h the height of the water above the bottom of the notch, then Q varies as $\sqrt{h^5}$. If $Q = 7.26$ when $h = 1.5$, find h when $Q = 5.68$.

17. The cutting speed at the circumference of a tap is given as between 15 and 20 feet per minute. What are the speeds of the following, and do they fall within these limits?

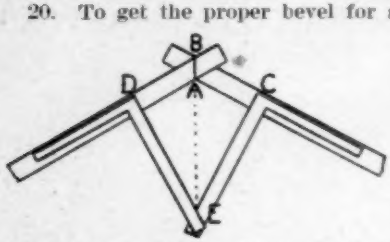
	Revolutions per minute:	
Diameter of tap.	Cast iron.	Wrought iron.
$^3/_{16}$ inch	340	265
½ inch	145	114
1⅛ inch	63	50

18. The diameter of the high-pressure cylinder of a steam engine is 30″ and that of the low-pressure cylinder is 64″. Find the ratio of the areas of the cross-sections of the two cylinders.

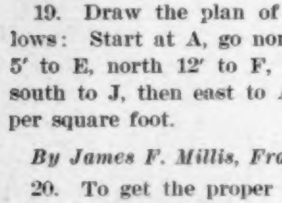
19. Draw the plan of the basement of a building to scale as follows: Start at A, go north 12′ to B, east 5′ to C, north 8′ to D, west 5′ to E, north 12′ to F, west 8′ to G, north 10′ to H, west 14′ to I, south to J, then east to A. Find the cost of cementing it at 15 cents per square foot.

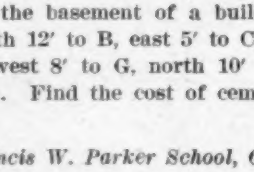
By James F. Millis, Francis W. Parker School, Chicago, Ill.

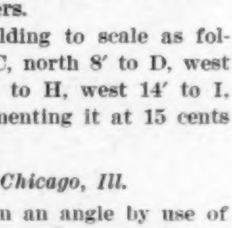
20. To get the proper bevel for a butt joint on an angle by use of steel square only: The timbers are placed at the required angle, crossing at B. It is required to locate the line AB properly. Space off equal distances BC and BD on the timbers. Square across at C and D, the squares crossing at E. BE gives the joint line required. That is, the timbers are cut at equal angles. Prove it.



21. To lay off a quarter-turn stair of three steps to the turn. Steps 1, 2, and 3 are to make equal angles at T.







22. To lay off a gambrel roof. AB = the span. Arcs BC and AE are each one-fifth of a semicircle.

23. Show how to construct this top sash of a window.

NOTE ON THE AMERICAN SYLLABUS IN ALGEBRA.

In the February number of SCHOOL SCIENCE AND MATHEMATICS appeared an excellent article by Mr. E. E. Whitford, on "The American Syllabus in Algebra." Among the syllabi in algebra issued by different mathematical societies and associations, I was surprised to note the omission from this article of any reference to the syllabus prepared by the Central Association of Science and Mathematics Teachers. This syllabus is one of the most progressive and most helpful to teachers of all the syllabi in algebra that have been published in the country. It has had a very great influence in determining the course of study in algebra in secondary schools, especially in the Middle West. Eleven thousand reprints of the report as it was first printed in SCHOOL SCIENCE AND MATHEMATICS were made and distributed to teachers throughout the country. Probably no other mathematics report in this country ever has had such a wide distribution as this one, or has made a greater contribution to the present movement to adapt elementary algebra to the modern practical needs of secondary school pupils.

JAMES F. MILLIS.

ANOTHER NOTE ON THE AMERICAN SYLLABUS IN ALGEBRA.

BY H. E. SLAUGHT,

The University of Chicago.

A distinct service has been rendered to the teachers of mathematics by the author of the article in the February number of SCHOOL SCIENCE AND MATHEMATICS, entitled, "The American Syllabus in Algebra." It is true that a great impetus has been given to the teaching of algebra through the nation-wide discussion which has been going on during the past few years, and Mr. Whitford has most opportunely gathered up the essence of these investigations and put them in a convenient tabular form for reference.

The purpose of this note is to call attention to one very important syllabus which evidently was overlooked by the author of this article in his enumeration of those which seem to be especially valuable, namely, the report of the committee of the Central Association of Science and Mathematics Teachers on Algebra in the Secondary Schools, which was made during the year 1906, reported at the meeting in St. Louis in 1907 and reaffirmed in Chicago in 1908.

Let us hope that the author's prophecy concerning the probable usefulness of the Middle States and Maryland syllabus may be amply fulfilled (though many teachers already recognize its serious weaknesses, not the least of which is its failure to make clear which topics or what portions of topics belong to the *elementary* course and which to the *intermediate*). But in any case its record of usefulness exists as yet only as *prophecy*, while that of the Central report has had a phenomenal record of three years during which it has never ceased to be in constant demand from all parts of the country, both by individuals and by associations. Literally thousands upon thousands of these reports have

been studied by teachers, north, east, south, and west. That the Central report has produced a profound impression is shown by many indubitable evidences, not the least remarkable of which is the quotation from a state syllabus which Mr. Whitford gives at the top of page 142 in his article, which in turn is a quotation *verbatim et literatim* from the Central report. Moreover, eleven pages of this same state syllabus, the entire portion devoted to algebra, are reproduced, word for word, from the Central report (with the possible exception of a dozen isolated words). This statement is not made to cast any reflection upon the makers of the state syllabus, except that they might properly under the circumstances have given credit to the Central Committee, but to show how fully the Central report has taken hold of the algebra teachers. Several other states have adopted syllabi embodying the main constructive features of this report, and teachers everywhere are recognizing that it is a far more important document than any mere itemized catalogue of all the algebraic theory and manipulations which have been collected during the nineteenth century could possibly be. They see in it a judicious and helpful sorting and distributing of the heterogeneous mass of algebraic material, in such a way as to aid the teacher in selecting appropriate matter and treatment for the various stages of development of the pupil, and they welcome the energizing and humanizing effect which the suggestions of this report have had upon the whole algebra situation. This is the only possible explanation for the widespread influence of this report.

REQUIREMENT OR RECOMMENDATION.

By C. R. Mann.

The University of Chicago.

In the February number of School Science and Mathematics, Mr. Franklin T. Jones discusses the timely question of requirement or recommendation. His conclusion that the so-called requirements for college entrance are really only recommendations is one that every teacher should take to heart and put into practice. Since they are recommendations only, we should take them at their face value.

But if the college specifications are only recommendations, has the teacher no requirements that he must meet? Are there any demands made upon him which he cannot well ignore? Let us see. Mr. Jones, following his policy of exalting college examination questions, prints a list of questions given last June, and asks: "Why should the per cent of failures in a list like the following be greater than 15%?" "Certainly," he answers, "not because we may not reasonably expect our average pupil to obtain 60% on it in two hours' time." The question is a good one, but the answer is purely rhetorical. It is simply an expression of the hortatory type of educational discussion that is, we hope, fast dying out. Whatever we may "reasonably expect" the average pupil to do, and whatever the colleges may "recommend" that the teacher do with the pupils, the facts are that more than 60% of

those who take the College Board Examination fail to answer four out of the twelve questions given. I have been unable to find the report of the board for this year and so cannot give the results for this particular set of questions.

The reason for this failure on the part of the students is that the teachers have regarded the college "recommendation" as their sole "requirement," and have failed to recognize the real requirement that is placed upon them by the needs and abilities of their pupils. The college "recommendations" have been framed with the idea of leaving the students with a clear, logical view of the whole field of elementary physics. No attention has been paid to the abilities of the students or to their needs and motives. We cannot expect any better results until we cease studying antique lists of college examination questions, give up regarding the "recommendations" of the colleges as of any great value, and begin seriously studying the ways in which pupils develop ideas of physical phenomena and the methods that may be used to strengthen and make clear those ideas. Therefore, while it is important that the teacher should regard the college examinations as "recommendations" only, it is far more important that he should recognize that he must meet the requirements that are determined by the nature of the pupils before he can ever hope to succeed in any better way than he is doing at the present time.

Under these conditions, it is probably not worth while adducing the statistics from the reports of the College Board in proof of the falsity of such statements as: "The requirements do and should check inefficiency." "The new requirement does not differ in spirit or in any essential particular from previous requirements." For love is blind: and whoever is enamored of the catechisms of an ancient faith does not take readily to a rational examination of the scientific facts on which the hope of the future is based. On the main point we are all agreed: college specifications of units are "recommendations"—advice only—and advice is proverbially cheap.

Fortunately for the students, the progressive public high schools have already ceased assailing the better colleges with cries of "College domination!" and have turned their attention away from these catechisms of the ancient faith with their musty scholastic puzzles. In like manner the more progressive colleges have ceased to believe that they can solve their educational problems by defining undefinable units on the basis of a metaphysical conception of what young people "ought to be expected to do." Both have turned to a scientific study of their common material and their common problem,—the body of human students that yearly passes from one to the other, and the best means of educating those students so that they may be of greatest service to their communities and their states. By their new systems of admission Columbia and Harvard have practically rendered the validity of the entrance examinations null and void; and the day is not far distant when we will all look back with wonder at the fact that, in a scientific age, anybody could ever have pinned his faith and even worshiped that most unscientific of all unscientific things—the system of entrance to college by examination only.

CALIFORNIA TEACHERS' ASSOCIATION—MATHEMATICS SECTION.

The Mathematics Section of the California Teachers' Association held its fifth annual meeting at the Mission High School, San Francisco, on Wednesday, Dec. 29, with a large and enthusiastic body of teachers in attendance. Dr. Charles A. Noble of the University of California, presided.

The first paper was on "The Accrediting of High Schools at the University of Illinois," by Dr. E. W. Ponzer of Leland Stanford, Jr., University. Special emphasis was placed upon the effect of accrediting in producing better balanced preparation both for the university and for lifework. The release from the cramming necessary in the old examination system has proved especially beneficial to all concerned. The discussion led by Mr. James C. Bryant of the San Jose High School was focused upon elementary algebra. The section seemed strongly in favor of taking at least one and a half years to carry the pupil well through quadratics, and also felt that one and a half entrance credits should be allowed this work by the universities.

Dr. E. R. Snyder of the San Jose State Normal School read a very carefully prepared paper on "The Natural Correlation between the Applied Arts and Mathematics in the Public Schools."

He brought out forcibly the great benefit to the pupil of actualizing his mathematics in concrete practical applications. Manual training, industrial arts, and all the sciences have a mathematical foundation and offer well-graded problems for the mathematics student in all his courses.

Miss Lucile Hewitt of the Alameda High School, opened a very animated discussion by telling of the wonderful variety of material she had found for graphs for her algebra classes and for geometric work.

The discussion revealed the fact that a large number of the best teachers of mathematics make free use of the "laboratory method" in developing and illustrating their work.

The third paper was given by Mr. F. E. Crofts of the Lowell High School, San Francisco, on "Present Demands upon Mathematical Teaching in Our Schools." He brought out very clearly the spirit of the present time which measures students by their efficiency and subjects by their contributions to this efficiency. The demands are just and reasonable; the subjects are fundamental; the modern teacher is progressive and gradually securing the required results.

Dr. Noble gave a touching and appreciative tribute to his long-time friend and colleague, Dr. Irving Stringham. For many years he was the head of the Department of Mathematics in the University of California, also Dean of its Faculty. At the time of his death he was Acting President.

A man of singular purity and nobility of character; of great ability, of wide and varying interests, yet of so sweet and lovable a temperament that his friends and students got very close to his great heart. His passing is a great loss to science and to humanity.

Dr. Charles A. Noble of Berkeley was re-elected President. Mr. F. E. Crofts of San Francisco was elected Vice-president. Mr. J. Fred Smith of Campbell was re-elected Secretary-Treasurer. SCHOOL SCIENCE AND MATHEMATICS was continued as the official organ of the section.

J. FRED SMITH.

JANUARY MEETING NEW YORK ASSOCIATION OF BIOLOGY TEACHERS.

Dr. Clifton F. Hodge of Clark University, Worcester, Mass., addressed the New York Association of Biology Teachers at The College of the City of New York, Friday evening, January 21, 1910, on "The Relation of the Biology of the High School to that of the College." Dr. Hodge has a national reputation because of his book "Nature Study and Life" which has influenced greatly the development of nature work in the schools below the high schools.

In his address he said that the child during his earlier years should be taught that biology which will help him in his home life; during the high school course should be taught that which will prepare him for his duties as a citizen, while the theoretical biology should be left to the college. In illustration of the work for citizenship he told how a class in Worcester, Mass., had, under his direction, cleared certain regions of malaria by their destruction of mosquitoes so that mills which had been running part time on account of the illness of their operatives were enabled to work full time and fill their orders.

Dr. Hodge also emphasized the necessity of interesting the pupils in the preservation of the native animals and natural resources of our country.

As this was the annual meeting of the association the following officers were elected: President, Martha F. Goddard, Morris High School; Vice-President, Clarence W. Hahn, High School of Commerce; Secretary, Lillian B. Sage, Washington Irving High School; Treasurer, Paul B. Mann, Morris High School; Fifth Member of Executive Committee, George W. Hunter, De Witt Clinton High School.

MINUTES OF THE CHEMISTRY SECTION, C. A. S. & M. T.

In the absence of Chairman Abbott, the section was presided over by Vice-Chairman Drake. The program was carried out as printed, and some of the discussions were lively. Because many teachers have both Chemistry and Physics—and more Physics than Chemistry—our attendance was relatively small as each teacher went to the section where his chief interest lay. To get all teachers of Chemistry together at next meeting, the officers for the ensuing year were instructed to make arrangements, if possible, for one joint session of teachers in Physics and Chemistry. The following officers were elected for the next year: Chairman, Dr. Albert L. Smith, Englewood High School, Chicago; Vice-Chairman, Prof. Geo. F. Weida, Kenyon College, Gambier, O.; Secretary, Miss J. Cora Bennett, East High School, Cleveland, Ohio.

C. M. WIRICK.

ASSOCIATION OF OHIO TEACHERS OF MATHEMATICS AND SCIENCE.

The Association of Ohio Teachers of Mathematics and Science held its seventh annual meeting in Chemical Hall, Ohio State University, Columbus, Ohio, December 28, 29, 1909.

At the sessions of the Science Section President Stella S. Wilson, Central High School, Columbus, presided, the Mathematics Section having for its chairman Vice-president Gordon N. Armstrong, Ohio Wesleyan University.

MATHEMATICS SECTION.

The History of the Development of the Theory of Numbers, Mr. J. H. Kindes of the University of Cincinnati traced the development of systems of notation and also of number theory, dealing particularly with the work of Euclid and Fermat. He set forth many of the historical problems of this branch, ending with some of the more recent problems.

On the general topic: The Technique of the High School Mathematics Recitation, Mr. R. A. Brown of Shaw H. S., E. Cleveland, treated of algebra, describing in detail his method of carrying no work in algebra, wherein the pupils were held strictly accountable for precision and accuracy, the passing grade having been correspondingly lowered. The paper brought out vigorous informal discussion.

In treating the geometrical side of the topic, Prin. D. R. Ellabarger of Piqua dealt with the pedagogical principles underlying the recitation, rather than describing any particular method. He emphasized the things to be attained by the student and dangers to be avoided by the teacher.

MORNING SESSION, WED., DEC. 29, 1909.

The Mathematics Section first adjourned to hear the mathematics papers of the Mathematics and Science section of the Ohio College Association.

Owing to the absence of Miss Gertrude Hadlow of Technical High School, Cleveland, her paper on Practical Mathematics for the High School was read by Mr. V. D. Hawkins of the same school. This paper was replete with illustrations of the practical problems which the Technical High School is using, drawn from buildings, trusses, ventilating systems, dress making, etc.

Teaching How to Study Mathematics was treated by Prof. J. P. West of the M. Boehm (Otterbein) Academy, both from the standpoint of pedagogy and psychology and also from his own practical experience in the work. Many practical suggestions were given, which would help the student to apply himself most effectively.

In discussing this paper Prin. C. H. Fullerton of the Indianola School, Columbus, emphasized the more important points with which he agreed.

In discussing the Round Table topics most interest was manifested in The Arrangement of the High School Mathematics Curriculum. On motion, a committee was appointed to report, next year, suggestions as

to the best arrangements of mathematics courses in the high school from the standpoint of the pupil who will go to college, and of those who will not go to college.

SCIENCE SECTION.

"Physics in Technical Schools" was the subject of a paper by Mr. V. D. Hawkins, Technical High School, Cleveland. He described the work being done in that school. Physics is taken up in a manner that gives the pupils direct application to the work they are to do, at the same time they are given some instructions in theories.

In a paper on "Some Achievements in Chemistry" Prof. A. M. Brumback, Denison University, gave some interesting accounts of the application of Chemistry to the industries. By the aid of the chemist many industries are making what were formerly waste products into useful articles of commerce.

Prof. Twiss, Ohio State University, explained the use of a very interesting device for showing longitudinal waves.

Charles E. Albright, North High School, Columbus, read a paper on "Should There be Two Courses of Physics in the High School? One for Boys and One for Girls." Mr. Albright believed there should be two courses, and maintains such courses in his work.

This paper created a spirited discussion that extended over the remainder of the time of the session.

D. B. Clark, Circleville High School, gave a paper on "The Chemical Laboratory."

J. C. Hambleton, East High School, Columbus, gave a paper on "The Use of the Lantern in Biology," and showed with the lantern some of the uses.

Wednesday morning Prof. Westgate of Ohio Wesleyan University gave to the general meeting a very interesting talk on "Glacial Erosion in the Selkirk Mountains," illustrating his talk by lantern slides.

Wednesday afternoon a party made an excursion to the steel plant.

Officers for the coming year were elected as follows:

Pres., Frank E. Miller, Westerville, Otterbein University.

Vice-pres., William T. Heilman, Columbus, North High School.

Sec.-Treas., Charles T. Prose, Zanesville, High School.

Ass't Sec., Harriet E. Glazier, Oxford, Western College for Women.

REPORT OF PHYSICS SECTION OF THE NOVEMBER, 1909, MEETING, CENTRAL ASSOCIATION OF SCIENCE AND MATHEMATICS TEACHERS. PHYSICS SECTION, 1909, CHICAGO.

Meeting called to order by Chairman C. H. Perrine.

Nominating committee appointed as follows:

F. E. Goodell, N. D. H. S., Des Moines, Iowa.
E. P. Reynolds, State Normal School, Platteville, Wis.
Fred Nichols, Crane M. T. H. S., Chicago.

Prof. A. A. Michelson presented a paper on some recent determinations in Physics.

Recent advances in spectroscopic research have rendered the older

methods obsolete. Study of the effects when radiation takes place in the magnetic field renders it necessary to read, not to one tenth, but to one hundredth or even to one thousandth of the separation of the Sodium lines. By means of the prism spectroscope readings may be taken only to about one thirtieth of this separation. The reasons for this limitation are practical rather than theoretical.

Rowland gratings enable us to read to one hundredth the separation of the sodium lines. Theoretically, the resolving power ought to be greater since it is proportional to the order of the spectrum, but because of decrease in illumination and overlapping of successive orders, the higher orders are of no more value than the first.

The interferometer is good in finding distance between lines, but it is of little value in complex groupings, is difficult to handle, and is slow in operation, so that changes in the magnetic field are likely to take place.

The Aschelon spectroscope aims, not to increase the order of the spectrum, but to increase the step, so that instead of 1, 2, 3 it is 50,000 light waves. The overlapping of the successive spectra then becomes difficult to untangle. An attempt has been made to separate the blue end of one from the red end of another by a prism at right angles to the first, but this decreases the intensity seriously.

As far as it goes, the grating is the most simple and the best method of spectroscopic study. To use the higher order spectra we must have larger gratings and the difficulty of ruling increases rapidly with an increase of size. Errors which amount to one millionth of an inch, if systematic, will produce visible results in broadening out the line, while systematic errors of one hundred-thousandth of an inch will produce "ghosts." "Ghosts" may be tolerated if they are not over one tenth the intensity of the fourth order spectrum—hence the systematic errors in ruling should not exceed one millionth of an inch.

In the machine now in use, some form of screw does the spacing. It is proposed to build a machine in which, by means of the interferometer, the length of the light waves themselves shall measure the spacing. In the present machine the principal difficulty is to grind a screw with sufficient accuracy. It would be easy to grind a screw two inches long with not more than .000001 inch error, but to make one twenty inches long is very difficult. It took Professor Rowland three years to grind one twelve inches long, and then it had so many inaccuracies, which he was able to correct in ruling, that no one has been able to use it since his death.

To make a screw twenty inches long, which will not sag, inch and a quarter stock is used. The screw comes from the lath with a "V" thread, about 50° and an accuracy not greater than one thousandth inch. This is then corrected by grinding inside a nut with fine emery. As the nut wears, it must be adjusted—hence it is made in three sections separated and held in place by a steel band, making it flexible at right angles to the axis, but perfectly rigid longitudinally. This reduces the error from one thousandth to one hundred-thousandth inch. A microscope will not discover this error, but the interferometer will,

and the errors are studied and corrected locally by repeated trial and correction for months. The residual error is then plotted on a cylinder of wood, which is cut to work in the dividing machine in such a way that its errors are equal and opposite to those of the screw.

The grating while being ruled must run on guides, which have a high degree of accuracy. Those on the machine now in use, if produced to a length of one mile, would be about one twentieth of an inch out of parallel.

The gratings are ruled on a heavy plate of speculum metal, which with the carriage, etc., weighs about thirty pounds. As the screw at each ruling makes a fraction of a turn, it advances the plate one twenty-thousandth inch. The great friction would soon wear it out—hence the carriage plate and all is floated in mercury. Professor Michelson closed his paper by projecting on the screen some of the mercury lines separated on a scale which would make the distance between the Sodium lines about eight feet.

Prof. Robert A. Millikan, Associate Professor of Physics, University of Chicago. "The Elementary Charge of Electricity."

The Physics section has realized that all advance research affects our elementary presentation of the subject. I will present first the research work of the last two or three years, which has silenced all opposition to the kinetic theory. Ostwald, who was the last scientific objector, has been converted as we now practically see the molecules vibrate.

What has been done in this laboratory is only a step in the series of experiments carried forward by other experimenters, notable among which is Pres. Rutherford's address before the British Association.

In working out Faraday's laws, I usually present them as follows:

1. If dealing with the flow of electricity through an electrolite containing hydrogen, as in an acid, the quantity of hydrogen liberated is independent of the kind of acid, and its concentration but depends only on the quantity of electricity. The quantity of electricity carried by one atom we call the atom of electricity.

2. If we deal with the same quantity of electricity, the weight of the element deposited is proportional to the atomic weight for a univalent element. That is, each atom of silver or hydrogen carries an atom of electricity, and each atom of a divalent element, as copper, carries two atoms of electricity, or total charge divided by total mass equals quantity on one atom divided by mass of one atom. If we can determine the number of atoms in a gram of hydrogen, we will be able to determine the number of atoms in a gram molecule of any substance.

In 1824, Mr. Brown discovered that certain particles held in suspension in a liquid were agitated. It has been almost one hundred years before anyone could explain the cause of these movements. The Brownian movement is due to the fact that the particles are becoming comparable in size to the size of the molecule. The number of impacts one side ceases to be equal to those on the opposite side and the particles get hit and knocked about—hence we are actually seeing the movement of molecules.

One experimenter has set up the experiment by making an emulsion

of gambosium in water. Then by using a milk separator on the emulsion he gets particles of a uniform size. These placed in a tube tend to settle under the influence of gravity and to diffuse under the molecular influence. He found that they follow the gas laws and by actual count, he found that the density decreased one half in one tenth millimeter, while the density of air decreased one half in a height of a little less than five miles.

Another experimenter has found the same Brownian movement in smoke particles in air—hence from these experiments we have a direct count of N. These movements of smoke particles have been photographed by the kinetoscope and the molecular movement is now so clear that the wayfaring man can't miss it. Using this count for N (the number of molecules in a gram molecule) gives 4.5×10^{-10} for E (the atom of electricity).

Mr. Bergman and myself used this summer a different method to find E. When radium is brought near air, the particles are knocked apart into + and — ions. We measured the charge in air. By suddenly exhausting part of the air in a chamber saturated with water vapor, we got a cloud, the water being deposited around ions. We then measured the charge on these drops. We had two plates with a potential difference of 30,000 volts with the — plate above. A + drop would then be drawn down by gravity and forced up by the electric charge toward the — plate. We were able to hold drops for 45 seconds. By timing the fall and rise of drops, we were able to determine E from these observations where E is balanced by g. mg = force down, XE force up, $mg = XE$ when balanced. By this method we found $E = 4.83 \times 10^{-10}$. The method of count previously mentioned gave $E = 4.5 \times 10^{-10}$.

In the spintharoscope, each spark is the impact of an (a) particle. By measuring the charge and counting the sparks Rutherford has found 9.30×10^{-10} as the charge on each particle. If each carries a double charge, this gives 4.65×10^{-10} for E. The mean of all results so far obtained is $E = 4.69 \times 10^{-10}$.

In the absence of Prof. O. W. Caldwell, his report of several experiments in first year science for High Schools was read by Mr. Bishop.

Prof. P. B. Woodworth of Lewis Institute, Chicago, gave a brief account of a course for certain boys in Lewis Institute. The class is composed of boys who have never had a High School course and have been working in shops from four to six years. They now work one week in the shop and the alternate week in Lewis Institute. They work eight hours each day and do no studying at home. Their program is as follows:

1. 8:30- 9:30. Physics Laboratory.
2. 9:30-10:30. Physics Lecture and Demonstration.
3. 10:30-11:30. Physics Mathematics.
4. 11:30-12:30. Physics English.

The afternoon program is for mechanical drawing, machine design, etc. They are in school 24 weeks, shop 26 weeks, and vacation 2 weeks each year. This gives about 900 hours of actual school work and they accomplish as much as the average pupil in regular school work who

has about 1,000 hours per year. They use no text-book, as the work is mimeographed.

Our regular first year boys have a science course running through the year, consisting of astronomy, physics, and chemistry. The physics is divided into Earth's crust and Good old Natural Philosophy. Our fathers enjoyed natural philosophy, why shouldn't our pupils?

Prof. Chute of Ann Arbor replied to this question by saying that our pupils *do* enjoy Physics. He had the question asked in four Michigan High Schools, no names to be signed—413 "yes" and 20 "no" was the vote.

Prof. Carhart of Ann Arbor said many teachers were teaching physics in smaller schools, who had had only one year of physics. He thought they were as well prepared as a German or a Latin teacher, who had had only one year of German or Latin.

Remarks by Nichols, Reynolds, and Shephard.

Meeting adjourned.

Saturday, November 27th, 1909.

The meeting was called to order at 10:30 by Chairman C. H. Perrine.

The nominating committee reported for Chairman, C. E. Spicer, Joliet, Ill.; Vice-Chairman, H. C. Krenerick, Milwaukee, Wis.; Secretary, C. F. Adams, Detroit, Mich.

The above officers were duly elected.

Mr. W. M. Butler, St. Louis, reported the meeting of the committee on College Requirements. This Committee was appointed by the College Entrance Board and met in the Library of Columbia University. The report has already been printed in SCHOOL SCIENCE AND MATHEMATICS. The chief thing accomplished is that a certificate is accepted for the laboratory work and no set list of experiments is required. The teacher is left free to improve.

Prof. Charles R. Mann submitted some suggestions as chairman of the committee on fundamentals. The committee had not held a meeting and some did not subscribe to all the articles—hence the report is not to be recorded as a committee report. Prof. Mann suggests that Dyne and Erg be left out of elementary physics and quantitative work on force producing acceleration be treated qualitatively rather than quantitatively, measurements to be taken in engineering units.

Mr. Jones moved that we accept report of the committee on fundamentals and discontinue the committee.

Moved to appoint a committee of one to meet with committee from mathematics and chemistry sections to consider standardization of terms in variation, proportion, and other topics, common to the subjects.

Mr. Goodell, Des Moines, Iowa, moved that we, as secondary school teachers, recommend that there should be "no quantitative treatment of kinetics or the behavior of matter undergoing acceleration."

V. D. HAWKINS, Secretary.

SCIENCE QUESTIONS.

FRANKLIN T. JONES,

University School, Cleveland, Ohio.

Readers of SCHOOL SCIENCE *are invited to propose questions for solution—scientific or pedagogical—and to answer the questions proposed by others or by themselves. Kindly address all communications to Franklin T. Jones, University School, Cleveland, Ohio.*

Questions and Problems for Solution.

19. *Proposed by G. B. M. Zerr, Philadelphia, Pa.*

An equilateral triangle has its altitude vertical and its vertex in the surface of water. 5/6 of its altitude is in water and 1/6 in a denser liquid. Find the density of this latter liquid if the pressure on the areas immersed in each liquid is equal.

20. *From an examination paper of Morris High School, New York.*

A circus performer stands on the middle of a slack rope. The parts of the rope make right angles with each other.. Calculate to one decimal the tension on each part of the rope, the weight of the performer being 120 lb.

Solutions and Answers.

17. *Proposed by Harold B. Reed, Cleveland, Ohio.*

A glass tumbler weighing 200 gm. is cooled from 20° C. to 8° C. when 240 gm. of water at 6° C. are poured into it. Find the specific heat of the glass. (Solve by simple analysis without use of formulae.)

Solution by Gertrude L. Roper, Detroit, Mich.

If the change in temperature of the water is from 6° C. to 8° C. for each gram, then

$$2 \times 240 = \text{number calories taken on by water.}$$

Similarly the amount of heat given off by 200 *g* in cooling from 20° C. to 8° C. is 200×12.

Since one substance is glass and the other water, we must take into account their specific heats: and, since there is to be no loss by radiation, we may write

$$200 \times 12 \times S_{glass} = 2 \times 240 \times S_{water}$$

Since water is to be taken as the standard $S_{water} = 1$ and

$$S_{glass} = \frac{2 \times 240}{200 \times 12} = .2, \text{ specific heat of glass.}$$

18. *From an examination paper of the High School, Montclair, N. J.*

Using a meter stick (weight = 140 gm.) a boy finds the weight of a trout to be 1260 gm. by suspending the fish from one end of the stick and balancing it on the edge of a knife blade. Find at what point the blade must be placed.

LITERARY NOTE.

"Lyell's Travels in North America in the Years 1841-2," 12mo, cloth, edited by Dr. John F. Cushing, Head Master of the New Haven High School, is among the new publications announced by Charles E. Merrill Company.

Lyell visited this country in 1841, having been invited to deliver the Lowell Lectures in Boston. He remained here until the fall of the following year and took the opportunity of traveling widely over a large portion of the northern and middle states. His work gives one a good account of men and manners in this country from the viewpoint of a foreigner.

The quaint, old-fashioned style will be admired for its simplicity; and the retention of the original spelling and punctuation will meet with approval. Lyell observed as a scientist and wrote as a scientist; and his cautious manner of expressing himself upon doubtful points appears time and again. He states nothing definite and decided unless his scientific mind has so determined it. The stimulant to the reader comes with the constant flood of contrasts or comparisons that are suggested by the text. Life in 1841 was in almost every respect different from the life of to-day; and the reader will unconsciously turn his thoughts to present-day affairs and compare them with the statements printed in this book. This suggestion of ideas is of great educational importance.

In the present edition, the first reprint since the original publication, the technical geological portions of the work have been omitted. The book is short and especially suitable for supplementary reading in the advanced grammar grades and high school classes. It will be sent postpaid by the publishers upon receipt of price, 30 cents.

BOOK REVIEWS.

The Calculus and Its Applications, by Robert G. Blaine, M.E., Lecturer at the City Guilds Technical College, Finsbury, London, E. C. Pp. ix+321. $1.50. 1909. D. Van Nostrand & Co.

"This work is the outcome of many years' experience in teaching the subject to students of very limited mathematical ability and attainment—experience gained, for the most part, under the best possible guidance, viz., that of Professor Perry."

This book is written on much the same line as Professor Perry's Calculus; a large number of practical problems are worked out in full, and a comparatively small number of problems and exercises are given for drill in differentiating and integrating. The problems demand less knowledge of physics and engineering than those in Professor Perry's text-book. It is the type of book which the newer American text-books in calculus are approaching. Though it does not give the student a thorough drill in rigorous proof and logical demonstration, it contains all of the really important principles and methods which an engineering student should master and take with him for use in his future engineering studies. There is a good discussion of practical methods of integration, and the problems in the integral calculus are well chosen.

H. E. C.

Primer of Sanitation, by John W. Ritchie, Professor of Biology in the College of William and Mary, Virginia. Published by the World Book Company, Yonkers-on-Hudson, New York. 1909.

The "Primer of Sanitation" is an attempt to put knowledge of the means of public and private health into such simple language that it may be understood by school children. It is written "with the hope that it may play some part in lessening the appalling economic and vital loss from preventable disease that is constantly sapping our nation's strength." The book is surprisingly comprehensive, considering that it consists of but two hundred pages. It is written in the simplest and most readable language that seems possible for the subjects that are treated. Illustrations of methods of infection are presented, which while not so unattractive as these things sometimes are, are still extremely forceful and cannot fail to attract attention of the pupils and convince them that the claims are well based. Records of the methods of infection in many cases are given, backed by statistics that are undeniable. All of the common diseases about which we have dependable knowledge are treated in such a specific way as to present a formidable array of interesting facts that certainly will, if studied, give a most valuable result in a better general knowledge of the conditions that make health possible. While this subject is always in danger of presenting the morbid side of disease, this book seems peculiarly free from this defect. The book will be found excellent for the purpose for which it has been written. O. W. C.

Our Insect Friends and Enemies, by John B. Smith, Professor of Entomology in Rutgers College. Pages, 314. Published by J. B. Lippincott Company, Philadelphia. 1909.

"Our Insect Friends and Enemies" is a book essentially upon the ecology of insects, with their relation to plant life holding a prominent place throughout the book. While we do not presume to criticise the book from an entomological point of view, certain features of a general ecological nature are distinctly worthy of mention. The topics treated are all grouped around the interrelations of insects to other things. The chapters deal with the relations of insects to the animal kingdom, to plants as benefactors and as destroyers, to other insects, to animals that feed upon insects, to weather and diseases that affect them, to other animals, to man as benefactors and as carriers of diseases, to the household, to the farmer and fruit grower; the book closes with a chapter upon "The War on Insects." The author disclaims any attempt at completeness from the point of view of the science of entomology, indeed he could not have made a readable book for the general reader had he made such an attempt, but his purpose seems rather to get together what is known of the phases of the subjects that he treats, much of which material he states that he has verified, and to present for the general student in an interesting way this information. In this attempt it seems that the book is quite successful, and should be found most helpful to the elementary and general student.

O. W. C.

Laboratory Botany for the High School, by Willard N. Clute, High School, Joliet, Illinois. 177 pages. Published by Ginn and Company, Boston.

"Laboratory Botany for the High School," by Willard N. Clute, is a detailed outline and is divided into three parts—the structure and life processes of angiosperms, the structure and evolution of the plant kingdom, and experiments in plant physiology. The first part, after brief chapters upon drawings and notes and the handling of the microscope, deals in order with the following plant topics; cells, seeds, roots, buds, stems, leaves, flowers, fruits and seeds, the study of trees and the ecology of the flower, the treatment of these comprising 88 pages of the book. Seventy pages are given to the second part, and twelve pages to the work in plant physiology. In the first part of the book no conspicuous attempt is made to relate the topics to one another, and apparently the teacher may change the order of presentation as desired. The second part of the book runs very closely along the lines of such books as Coulter's "Plant Structures" and Caldwell's "Plant Morphology," and presents the usual type forms in the order of increasing morphological complexity. The third part consists of 36 experiments related in general to the development of plants from seeds and seedlings to adult plants, and to securing raw materials, their transportation, the manufacture of foods, and elimination as related to food making.

The plan of work is first by means of description or descriptive questions to present the chief structures and terminology of the parts of the thing studied; then follows a long list of questions designed to stimulate careful individual observation upon details of structure and relation of parts; lists of review questions, frequently suggested additional studies, and lists of terms used together with their definitions close the treatment of each topic. In connection with the study of trees a seven-page key for identification of common trees is presented. It will be interesting to know whether teachers find these long lists of questions—sometimes well toward a hundred upon one topic—helpful in teaching botany. They are designed to "relieve the teacher of much of the labor of such investigations," and doubtless will often meet the desired end. Some will question whether the scientific attitude is so well fostered by a long list of detail questions as by a shorter list of general questions. The latter are thought by many to stimulate more careful and more connected observation of phenomena, as compared with finding the specific answer to one question, then looking for the next question in order to find the next specific answer. With very young pupils specific questions must often be used in order to secure definiteness of observation, but as early as possible in the process of science education students should learn to look upon the materials at hand as embodying a problem toward which by means of general questions they have been directed. Following a careful study of the materials, in process of quiz or review, detail questions are necessary and find their real use. However teachers may look upon this matter, all will find the book suggestive of things that they may do in their high school courses. O. W. C.

The World's Commercial Products. A Descriptive Account of the Economic Plants of the World and of Their Commercial Uses. Pages 391, with many illustrations. By W. G. Freeman and S. E. Chandler of the Imperial Institute, London, with contributions by T. A. Henry, C. E. Jones, and E. H. Wilson. Published by Ginn and Company, Boston. $3.50. 1908.

"The World's Commercial Products" deals with the products of the plants that are most useful to men. The place of cultivated plants in the work of the world is set forth in the introduction, and we are reminded of the statement in De Candolle's "The Origin of Cultivated Plants," that "Men have not discovered and cultivated during the last two thousand years a single species that can rival maize, rice, the sweet potato, the potato, the bread fruit, the date, cereals, millets, sorghams, the banana, the soy. These date from three, four, or five thousand years, perhaps even in some cases six thousand years." Notwithstanding this fact that these plants were discovered so long ago, it is evident that recent times have added much to the productivity of these things, and to the methods by means of which they may be properly cared for both in processes of growth and in harvesting. Many of the modern methods of treatment of these plants are included in the book, and excellent photographs, some of which are in color, are used to present conditions under which the various plants are grown, harvested, and marketed. World-wide work was necessary to collect all of the materials for the book, and indeed it presents in an excellent way a comparative study in the world's methods of cultivation, harvesting, and marketing its leading plant products.

In some parts of the world the plants that are grown are the direct and essentially descendants of those used centuries ago, while in others plant breeding has resulted in developing types of plants that are scarcely recognizable as the relatives of those from which they were derived. In some parts of the world the tools and methods used are those of ages ago, while in others the motor plow and reaper are in use. A study of the book adds to the evidence which shows that the most propitious climates are not the ones in which the greatest improvements in horticulture and agriculture take place. But where men must plan for a time of want, they develop the foresight that advances civilization. Winter and times of drought are types of the mainsprings of progress in agriculture as in other lines of progress—perhaps the lines upon which other lines of progress depend. The reaper, the electric propeller, and other great devices for better doing the work of agriculture and manufacture are products of regions in which there is a period of non-productiveness of the soil. Garnering for a time of possible need has enabled people in less propitious climates to devise appliances and methods of treating plants, which, when applied to the plants and processes of the more propitious regions, has greatly increased their capacity to produce. This interpretation of the world's progress in plant production seems well borne out in the excellent maps giving the distribution of the economic plants, accompanied by the discussion of the parts of the world in which they are best cultivated. The topics treated may be illustrated by the following partial list: wheat, barley, rye, oats, rice, wild rice, maize, millets, starches, sugar, cocoa, tobacco, coffee and tea, fruits, rubber, the various textiles, drugs, tans, dyes, oils, fats, and spices. O. W. C.